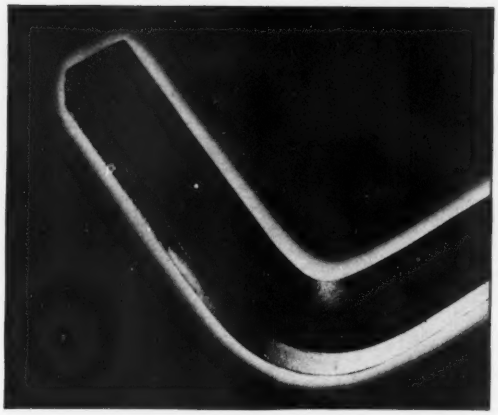
tech engineering news

february 1953

90° BEND AT 98 BELOW! This sample, flame-cut from 1" CARILLOY T-1 plate, was chilled to -98°F., and then bent to a full 90° angle. Even though the raw, flame-cut edge made up the outer radius of the bend, there was no sign of failure!



New steel has yield strength of over 90,000 psi yet remains ductile at 70°F. below zero even after welding or flame-cutting

100% WELD STRENGTH—Tensile tests on T-Steel specimens like these were made to determine the strength of the welds. These welds develop the full strength of the parent metal. Note that breaks occur outside the heat-affected zone, showing that the heat of welding has not harmed the strength of the material. No special pre-heating or post-heating treatments are required beyond those used with ordinary structural steels.

THIS remarkable steel, U·S·S CARILLOY T-1, offers great promise to those who need a super-strong steel that can be welded, flame-cut or cold-formed.

CARILLOY T-1 is unique. It differs from all other very strong steels in important respects: Its yield strength of over 90,000 psi is *not* lowered by welding or flame-cutting. In these operations, no pre-heating or stress-relieving is required. As a result, CARILLOY T-1 can be readily field welded.

Usually, welded steels of such high strength level suffer a loss of ductility at low temperatures unless elaborate precautions are taken in the welding operation. In striking contrast, notched bend weldability tests show that T-1 steel will remain ductile and tough down to the lowest atmospheric temperatures. As a matter of fact, T-1 steel, after flame-cutting, has been bent to a full 90° angle at temperatures as low as -100°F., without any sign of cracking.

Service tests show that CARILLOY T-1 is well suited for extremely abusive service, and the fact that it can be field welded should greatly lower the difficulties and cost of major repairs. In applications in which tension is the principal stress, thicknesses can often be reduced to one-third of those required with ordinary structural steels.

CARILLOY T-1 steel is another result of United States Steel's active research program which has enabled manufacturers to improve their production methods and make better products, too. All over the country, trained U. S. Steel engineers and metallurgists are constantly at work on problems like this, finding better ways to make and use steel. United States Steel Corporation, 525 William Penn Place, Pittsburgh 30, Pa.

USS

UNITED STATES STEEL

Graduate Engineers!

ENJOY GOOD SALARY FROM THE FIRST DAY... INTERESTING CHALLENGES RIGHT AWAY!

At Sperry you can apply your knowledge immediately and keep on learning—with pay—in research, product development, or field work. Salary increases come as you progress.

You enjoy the advantages of working with the leaders in their fields. You are expected to use originality and a fresh approach. Every project is a creative challenge to the brain-work and the team-work of the Sperry engineering staff.

VARIETY OF OPENINGS

There are opportunities for aeronautical, electrical, electronic, mechanical engineers – physicists – technical writers and field engineers for applied engineering.

ATTRACTIVE LOCATIONS
GOOD WORKING CONDITIONS

Long Island—In pleasant suburban atmosphere but convenient to New York. Modern plant. Well equipped laboratories. Excellent working facilities.

In the Field—There are excellent applied engineering opportunities in various sections of the United States and abroad.

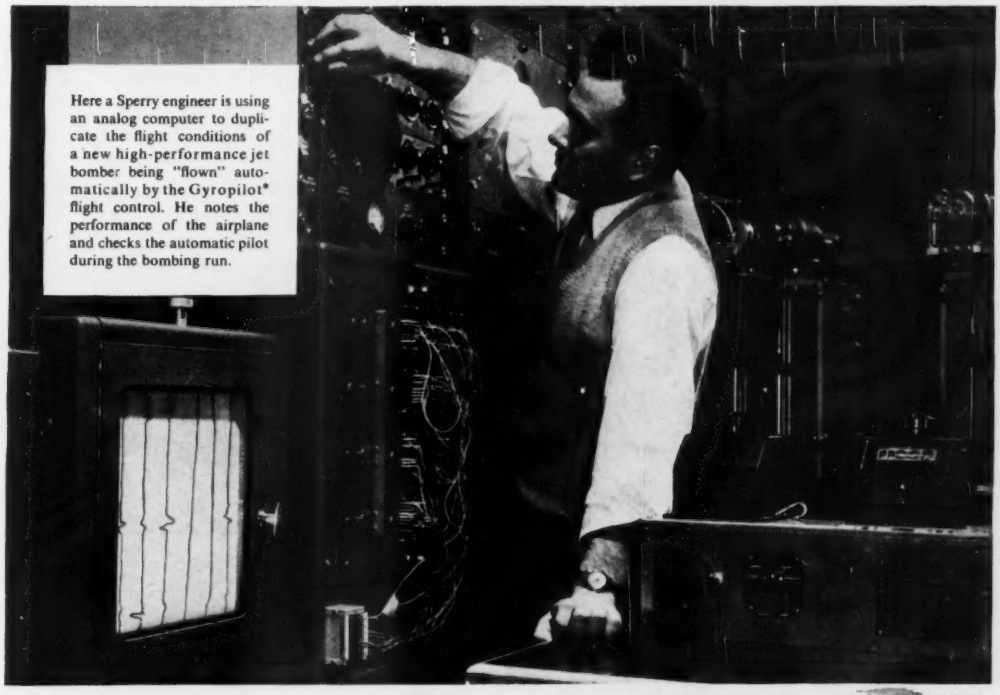
In All Locations—The way is clear for steady advancement. You are encouraged to continue your education while you earn. And liberal employee benefits are provided for all.

RESEARCH LEADERSHIP...
A FORTY-YEAR TRADITION

Today Sperry is the recognized leader in developing automatic controls for navigation. From Sperry's work in gyroscopics and electronics have come the Gyropilot* flight controller, Zero Reader* flight director, radar, servomechanisms, computing mechanisms and communications equipment.

Sperry sponsored the development of the klystron tube—the first practical source of microwave energy. From Sperry pioneering has come a complete line of Microline* instruments for precision measurement in the entire microwave field.

CHECK YOUR PLACEMENT OFFICE FOR DATES WHEN SPERRY REPRESENTATIVES WILL VISIT YOUR SCHOOL...OR WRITE SPERRY EMPLOYMENT SECTION 1A5-

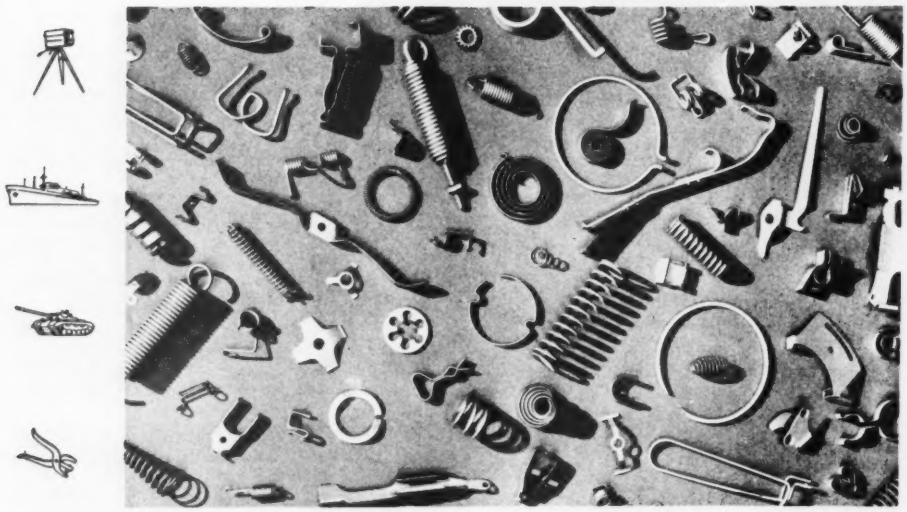


Here a Sperry engineer is using an analog computer to duplicate the flight conditions of a new high-performance jet bomber being "flown" automatically by the Gyropilot* flight control. He notes the performance of the airplane and checks the automatic pilot during the bombing run.

SPERRY GYROSCOPE COMPANY
DIVISION OF THE SPERRY CORPORATION

*T.M. REG. U. S. PAT. OFF.

GREAT NECK, NEW YORK • CLEVELAND • NEW ORLEANS • BROOKLYN • LOS ANGELES • SAN FRANCISCO • SEATTLE
IN CANADA – SPERRY GYROSCOPE COMPANY OF CANADA, LIMITED, MONTREAL, QUEBEC



Whatever you do . . . Wherever you go . . .

Wallace Barnes Springs

will help you do it

WALLACE BARNES CO., BRISTOL, CONNECTICUT

There's great new opportunity for Engineers in Honeywell's growing Aeronautical Division

The delicately balanced glass of water below clings to its perch, despite the plane's sharp banking turn.

That's because a Honeywell electronic autopilot is in command . . . the human pilot nowhere near the controls.

So precisely are the control surfaces coordinated, that all displacing forces are instantly equalized.

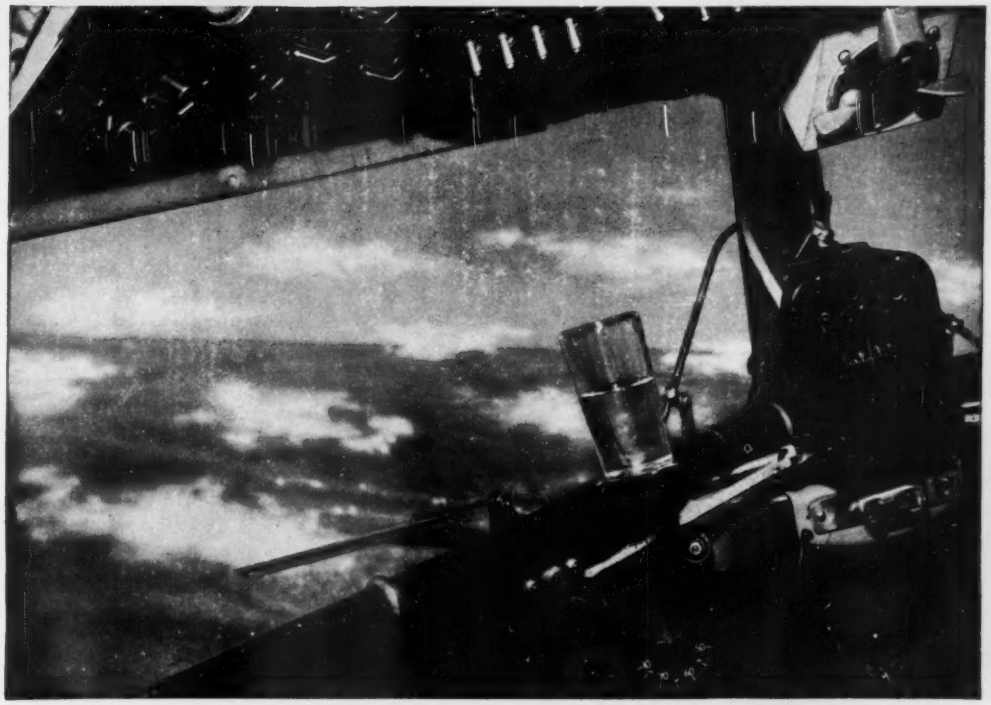
There simply can't be any skidding or side-slipping to upset the glass.

This is typical of aircraft performance made possible by controls produced in Minneapolis by Honeywell's expanding Aeronautical Division.

Besides autopilots, Honeywell's list of current aero products includes electronic fuel measurement systems, dozens of different kinds of gyros, actuators and many other controls.

Today, with aircraft and rockets flying even higher and faster, demands for new controls are being met in the new Honeywell aero plant pictured at left. In developing these new controls, the men in our expanding engineering and research sections often must work in the realm of pure science.

There's real opportunity for engineers at Honeywell—for this is the age of Automatic Control. And Honeywell has been the *leader* in controls for more than 60 years!



The world lives better—works better—with Honeywell Controls

MINNEAPOLIS **Honeywell**

First in Controls

SEND COUPON FOR MORE INFORMATION

MINNEAPOLIS-HONEYWELL REGULATOR CO.
Personnel Dept., Minneapolis 8, Minnesota

Gentlemen: Please send me your booklet, "Emphasis on Research" which tells more about engineering opportunities at Honeywell.

*Name*_____

*Address*_____

*City*_____ *Zone*____ *State*_____

tech engineering news

February 1953
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FRONTISPIECE

Contrast

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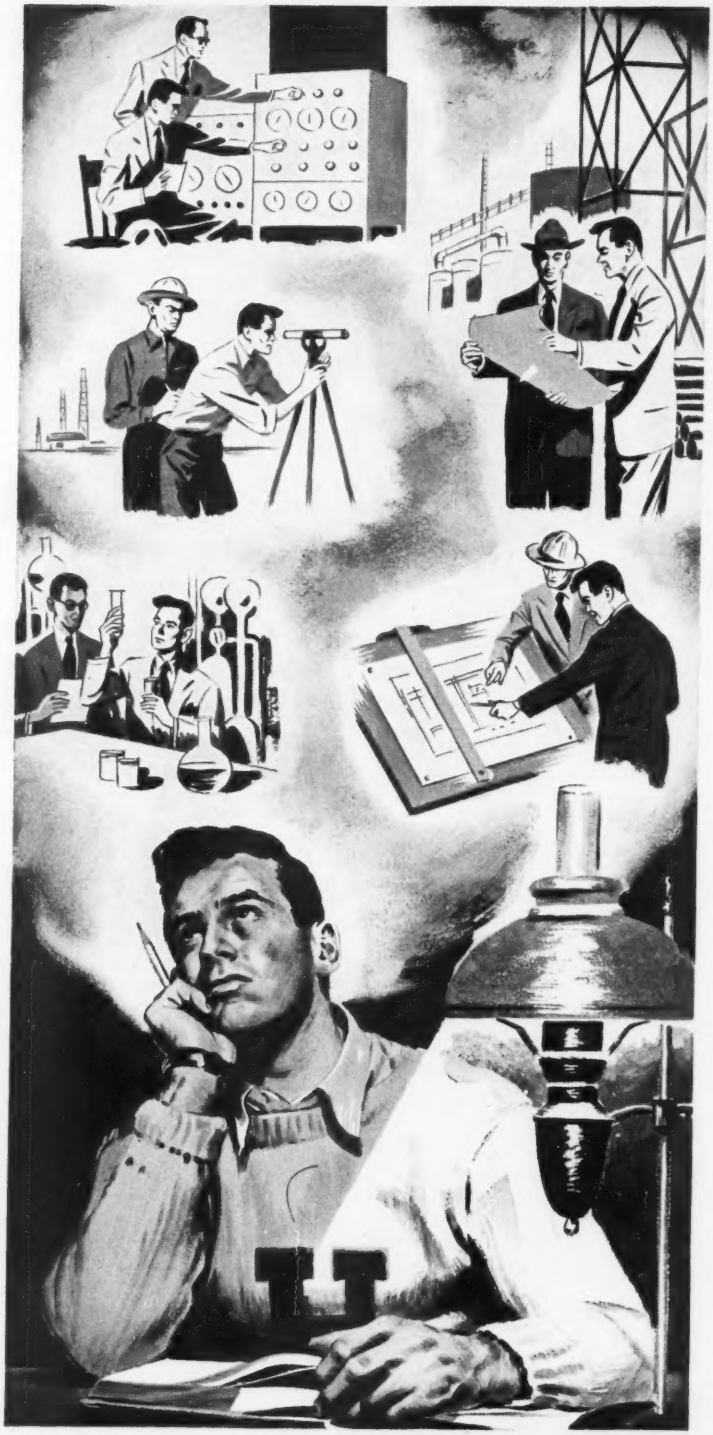
What Can Phillips Offer the Technical Graduate?

Of the more than 22,000 employees of Phillips Petroleum Company, 2200 are technical graduates . . . chemists, physicists, geologists, and virtually every classification of engineering specialist.

So versatile is petroleum as a raw material, and so complex are the processes whereby it is brought from the ground and converted into finished products, that its utilization requires technical men of the very highest competence in research, exploration, production, refining, chemical manufacturing, and transportation. To the talented technical graduate Phillips offers a chance for on-the-job training, and assignments of responsibility and importance.

Phillips has been and still is primarily a producer of motor fuels and lubricants. But today's rapid expansion in new fields of petrochemicals and high polymers offers unique opportunities for ambitious engineers and chemists.

We invite qualified men to write to our Employee Relations Department for information about opportunities with our company.



Phillips 66

PHILLIPS PETROLEUM COMPANY

Phillips Chemical Company, a Subsidiary

Bartlesville, Oklahoma

An invitation to Grow with Goodyear

No other company engaged in the manufacture of aircraft and plane components offers you such a wide variety of opportunities as Goodyear Aircraft Corporation—for more than 40 years an important contributor to America's progress in the air.

Goodyear pioneered in the use of high strength aluminum alloys in this country, contributing to the development and applications—and has long since become one of the leaders in light metals, design and fabrication. Countless developments, including the first pneumatic airplane tire in 1910, airplane wheels, disc type brakes, cross-wind landing gear, have helped to build aviation's present position.

In World War II, Goodyear Aircraft grew to be one of the nation's largest producers of military aircraft—producers of complete military aircraft *and* of components for more than a dozen front-line ships of all classes. Today, too, GAC is still active in this field.

In lighter-than-air, Goodyear Aircraft is the world's largest builder of airships, including the new Navy N-type airship—which is the largest non-rigid airship ever built, being nearly twice the size of the K-ships of 1941-45.

Long the leader in its field, Goodyear Aircraft Corporation is again vitally concerned with defense projects. But we go far beyond anything the past has produced. Our output now includes complete airships as well as many aircraft components. We are also active in many other new fields—ranging from plastics fabrication and design to guided missiles and electronic computers.

This wide variety of production, coupled with a desire to build and maintain an outstanding engineering staff, enables us to issue you this invitation to grow with Goodyear Aircraft. You'll find unlimited opportunity for advancement—*and an assured future*—at Goodyear Aircraft.

ENGINEERS WANTED

to investigate the outstanding opportunities in research, design and development of:

AIRPLANES, AIRSHIPS, HELICOPTERS, GUIDED MISSILES, AIRCRAFT COMPONENTS, WHEELS AND BRAKES, GROUND-AIR AND SHIPBOARD RADAR STRUCTURES, ELECTRONIC COMPUTERS, GUIDANCE SYSTEMS, TRANSPARENT ENCLOSURES, REINFORCED PLASTICS, RADOMES, BONDED SANDWICH STRUCTURES and many more.

Submit a brief resumé of your qualifications and experience or write us today for an application blank and further information. Prompt consideration is assured. Address SALARY PERSONNEL DEPARTMENT, GOODYEAR AIRCRAFT CORPORATION, Akron 15, Ohio.

GOODYEAR—The Company With COMPLETE Coverage of the Aeronautical Field

GOODYEAR AIRCRAFT

You can elect an electronic future at GM

The engineers in the picture are using a very simple looking little instrument called the Surfa-Gage.

Yet it is one of the most important contributions of the electronic age to quantity production of quality products.

For the Surfa-Gage allows production engineers to measure the surface of a part to determine the part's conformance to specified smoothness—within micro-inches — and thus insure greater wearing qualities.

We mention the Surfa-Gage here as just one example of the continuous General Motors developments in the field of electronics — from new airplane bombsights and tank range finders to improved car ignition systems, radios and controls for many manufacturing processes.

For we want the soon-to-be-graduated electrical engineer to know that he will find as wide a latitude for his training at GM as will the mechanical or metallurgical engineering student.

After all, the development of modern GM products—of all kinds—requires the development of tools to build those products. And this means a tremendous amount of work in electrical engineering—from the research lab to the production line.

So to the electrical engineer as to engineers in the other categories listed at right—we say there may well be a job with an interesting future for you at GM. Why not ask your College Placement Office to arrange a meeting for you with the GM College Representative the next time he visits your campus. Or drop us a line.

GM POSITIONS NOW AVAILABLE IN THESE FIELDS:

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Electrical Engineering
Metallurgical Engineering
Industrial Engineering
Chemical Engineering

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Personnel Staff
Detroit 2, Michigan

Your guardians of quality in radio, television and recorded music

When you see these trade marks on television sets, radios, "Victrola" phonographs, and other electronic instruments you are always assured the highest quality—born of leadership in research, fine engineering and craftsmanship.

The sun never sets on these trade marks, and millions of people around the world turn to them with confidence.

RCA, as the pioneer in the field, continues to lead in every major advance . . . in all phases of television.

RCA Victor has made radio a household word to millions of Americans. "Victrola" phonographs have extended great music from concert halls to homes everywhere, from Broadway to Every Street, U.S.A.

You also see these trade marks on records so rich in "living presence" that artists seem to be performing in your home.

Little Nipper and the familiar phrase "His Master's Voice" have appeared on recordings made by the world's greatest artists—for more than half a century.

These same high standards of quality make NBC the nation's leader in radio and television broadcasting. You can depend on RCA and RCA Victor trade marks as *guardians of quality*—sure guides to finer performance, dependability, better value and service.

Tmks. ®

CONTINUE YOUR EDUCATION WITH PAY—AT RCA

Graduate Electrical Engineers: RCA Victor—one of the world's foremost manufacturers of radio and electronic products—offers you opportunity to gain valuable, well-rounded training and experience at a good salary with opportunities for advancement. Here are only five of the many projects which offer unusual promise:

- Development and design of radio receivers (including broadcast, short-wave and FM circuits, television, and phonograph combinations).
- Advanced development and design of AM and FM broadcast transmitters, R-F induction heating, mobile communications equipment, relay systems.
- Design of component parts such as coils, loudspeakers, capacitors.
- Development and design of new recording and producing methods.
- Design of receiving, power, cathode ray, gas and photo tubes.

Write today to College Relations Division, RCA Victor, Camden, New Jersey. **Also many opportunities for Mechanical and Chemical Engineers and Physicists.**

RCA *RADIO CORPORATION OF AMERICA*

World leader in radio—first in television

230 MINUTES COAST TO COAST
. . . WITH A PRATT & WHITNEY ENGINE

Three hours and fifty minutes from California to Florida
. . . that's the almost incredible
cross-country record set by a Lockheed Starfire.

Now our engineers are developing the powerplants for
the outstanding aircraft of the future, both military
and commercial.
They are working on far more powerful jet engines
. . . even a nuclear engine.

If you would like to work for a company with a future
. . . serving an industry with an unlimited future . . .
set your sights on Pratt & Whitney Aircraft.

MORE AIRCRAFT ENGINES
BEAR THIS EMBLEM
THAN ANY OTHER.

Pratt & Whitney Aircraft
DIVISION OF UNITED AIRCRAFT CORPORATION
EAST HARTFORD 8, CONNECTICUT U.S.A.

briefing the news

Phonograph-needle drag distortion

A recent study demonstrates the existence of a type of distortion sometimes arising in ordinary record players. The study demonstrates that, if a phonograph needle can move tangentially with respect to the groove of an ordinary laterally recorded disk, the needle will not follow perfectly the lateral excursions of the groove, and "drag distortion" will result. In the playing back of recorded music, this distortion may apparently result in spurious tones of greater amplitude than the tones originally present.

The essential mechanism of drag distortion is not difficult to understand. The usual type of disk phonograph record is recorded laterally — the audio-frequency motion of the recording needle is at right angles to the record groove. For ideal distortion-free reproduction of recorded music, the motion of the tip of the playback needle or stylus should exactly duplicate the original lateral motion of the recording stylus. Provided the electrical output of the reproducing pickup is proportional to the lateral displacement of the reproducing stylus, the electrical output of the pickup will then be undistorted. But if forces acting on the stylus cause tangential motion, its lateral motion will no longer exactly duplicate the motion of the recording stylus, which means that distortion will be introduced. Many possible causes for such longitudinal motion can be suggested. One is the "pinch" effect due to the uneven width of the record groove. Another is the varying force which the sides of the record groove exert against the stylus.

The study included both mathematical analysis and laboratory experimentation. The mathematical treatment indicates that if the recording consists of a pure tone of constant amplitude, drag distortion will introduce only even harmonics, with the second harmonic predominating. A sudden transition from one amplitude to another will produce a large change in the tangential force on the stylus, and this may be expected to give rise to transient distortion if the needle is not properly restrained tangentially.

Although the effects of drag distortion can apparently be serious with some pickups, the investigators point out that the styluses of the better modern pickups have high tangential stiffness; with such pickups, drag distortion is probably negligible. It appears probable also that a form of drag distortion may arise in the recording operation if the recording stylus is not sufficiently rigid.

The investigation of phonograph-needle drag distortion was a by-product of the military research program. Telemetered information from experimental weapons is frequently recorded on disks, and the distortions introduced in the recording and reproducing processes are sufficiently serious at times to cast doubt on the significance of indicated measurements. Analysis of possible sources of error in these recorded measurements led to the study of distortion introduced by phonograph-needle drag.

Note: This work is reported in detail, with mathematical analysis, in "Phonograph Needle Drag Distortion," by J. Rabinow and E. Codier, *J. Acoust. Soc. Am.*, Vol. 24, No. 2 (March 1952).

Compri-dimensional extrapolator

It was announced recently by D. E. Merden, Professor of Sybophysical Biometry at H. S. U., famous for his work on semifinite Mertrix functions, that by using a cryptocoded feedback bork with two synchronized areameter pulses, he was able to apply the compri-dimensional extrapolator to problems in sociorganic metamorphosis of static forms of cronemic Isoptera. The pulses are put out by three primary sources. The first is a hypothetical source which does not exist. The second is empirical although it has never been obtained

by direct experiment. The third is the Schulenpfoffer triple monocouplet.

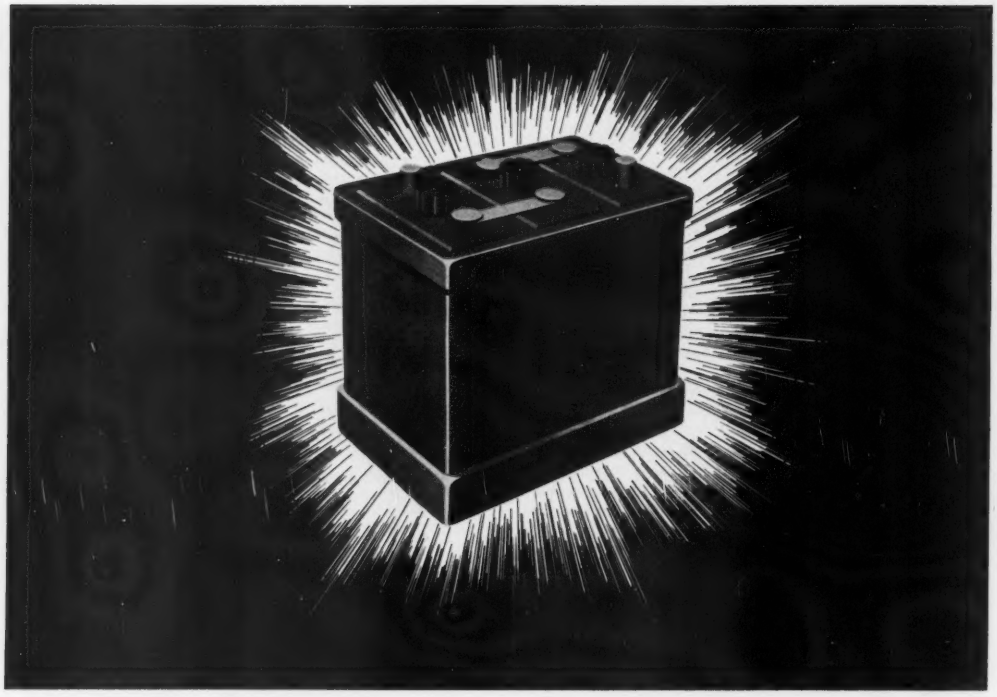
Most powerful radiation source

Twice the world's present supply of radium, which if obtainable would cost $130,000,000, would be needed to equal in intensity the rays from a powerful radiation source recently installed at the Knolls Atomic Power Laboratory. So intense is this radiation that it causes a bluish-white glow in the nine-foot depth of protective water under which the source is kept. When the room is darkened, the tank and the surrounding area are illuminated by this glow.

The source consists of 2.5 pounds of a radioactive form of the metal cobalt, known as cobalt 60. The radiations emitted are gamma rays or high-energy X-rays.

Physical properties of many materials to be used in constructing an atomic power plant may be altered by the powerful rays generated in the atomic reactor. By lowering samples of these materials into the water, and exposing them to rays from the cobalt 60, such effects may be tested on a small scale.

The radioactive cobalt is contained in ten cylindrical capsules, mounted in holes in a steel plate. They are kept at the bottom of a concrete pit and, with the aid of submerged lights, may be clearly seen through the nine feet of water covering them. Remote control devices permit them to be handled at a distance if necessary, and allow test samples to be placed in position around them.



PICKLED AMPERES...

That was the term used to describe the first storage batteries. For a score of years they were considered laboratory playthings, for they were crude, undependable, and required months or years to charge.

Their counterpart today is a reliable source of electrical energy . . . to start cars . . . to operate submarines, mine cars, materials handling equipment . . . and to perform over 200 other regular and emergency functions on land, sea and in the air.

CELLS—BRAIN AND BATTERY...

Storage batteries were conceived in France and England . . . but grew up in America. For Americans foresaw their commercial usefulness. Scientists performed experiment after experiment—thousands of them—to find the elements and chemicals with the best electro-chemical behavior . . . investors helped get production started . . . industry developed new applications . . . and today they build batteries by the millions.

AMERICA WORKS THAT WAY...

Each spark of genius electrifies dreamers, designers, engineers, executives, producers and purchasers. And the power behind our progress is America's all-seeing, all-hearing and reporting Inter-Communications System.

THE AMERICAN INTER-COM SYSTEM...

Complete communication is the function, the unique contribution of the American business press . . . a great group of specially edited magazines devoted to the specialized work areas of men who want to manage better, design better, manufacture better, research better, sell better, buy better.

COMMUNICATION IS OUR BUSINESS...

The McGraw-Hill publications are a part of this American Inter-Communications System.

As publishers, we know the consuming insistence of editors on analyzing, interpreting and reporting worthwhile ideas.

We know that businessmen, in order to keep abreast of their jobs, subscribe to—pay for—McGraw-Hill magazines edited for their specific business interests . . . for the editorial pages tell "how" and the advertising pages tell "with what."

McGRAW-HILL PUBLISHING COMPANY, INC.

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HEADQUARTERS FOR BUSINESS INFORMATION

What Are They?

- ☐ *Thrust bearings*
- ☐ *Clutch disks*
- ☐ *Grinding wheels*
- ☐ *Ceramic insulators*

The correct answer is grinding wheels, shown as they emerge from the electric kiln.

Not ordinary grinding wheels, however. They are Norton *New-Process* Wheels — made by modern, streamlined, precision methods developed by Norton engineers.

A Big Step Forward

This new process involves advanced equipment, new manufacturing techniques, and close quality control during every step of grinding wheel production. As a result, Norton *New-Process* Wheels are produced to a degree of structural uniformity never before possible.

This increased uniformity means extra assurance of consistent grinding action throughout each wheel and from wheel to wheel. Which, in turn, means more evenly wearing, longer lasting wheels — together with more cutting action per wheel and per dollar.

In addition, the built-in balance of Norton *New-Process* Wheels cuts down vibration and enables them to hug the work more closely, assuring smoother, better grinding performance.

A wide range of wheels employing both ALUNDUM* (aluminum oxide) and CRYSTOLON* (silicon carbide) abrasives are made by the new process.

Looking Ahead With Norton

Geared to industry's constantly expanding needs, Norton Company serves *every* manufacturing field by "making better products to make other products better." Young men planning technical careers are invited to consider the established leadership and far-ranging scope of the Norton world-wide organization.

Send For Additional New-Process Facts

Recent Norton literature gives further details on this important advancement in grinding wheel manufacture and performance. Write for your free copy.

John J. Amero, M. S., Cer. Eng., North Carolina State '38, checks duplication of grinding wheel grade with the aid of an oscillograph. John has been working on the development of Norton "New Process" wheels.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

NORTON

TRADE MARK REG. U. S. PAT. OFF.

Making better products to make other products better

ABRASIVES · GRINDING WHEELS · OILSTONES · ABRASIVE PAPER & CLOTH

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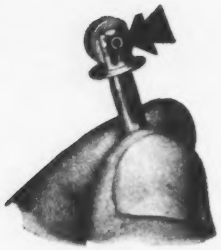
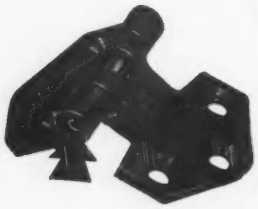
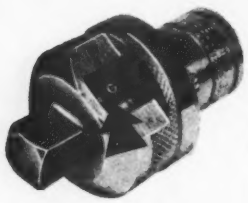
BEHR-MANNING, TROY, N. Y. IS A DIVISION OF NORTON COMPANY



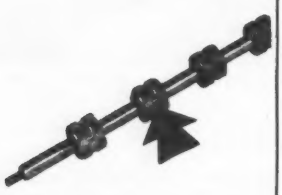
Replacing a rivet



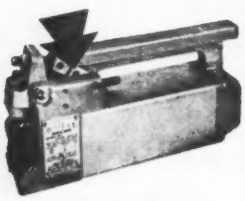
. . . a hinge pin



. . . a stop pin

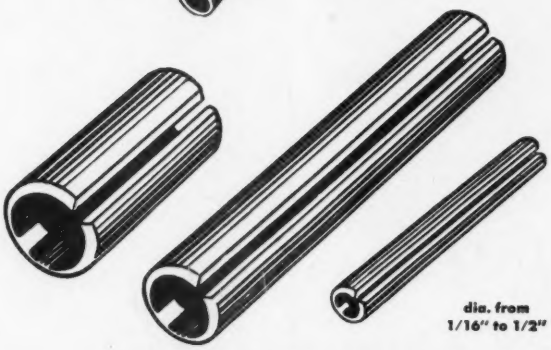


. . . a set screw



. . . a bolt and nut

ROLLPIN



dia. from 1/16" to 1/2"

. . . a modern fastener that saves time and money on thousands of applications

Rollpin is a hollow, split, cylindrically formed pin with chamfered ends. It is simply driven into holes drilled to normal production tolerances. Because Rollpin is slightly larger than standard sized holes, it compresses as inserted. It is self-locking—and vibration-proof—because of the constant pressure it exerts against hole walls. Its shear strength exceeds that of a cold rolled pin of the same diameter. Rollpin is readily removed with a drift or pin punch—and can be reused.

Because of its versatility—and the production economies it makes possible—Rollpin is finding wide usage in almost every phase of manufacturing activity. Write for design information on the Rollpin. It will enable you to cut costs for many applications where use of rivets, set screws, dowels, and straight, serrated or cotter type pins create installation or performance problems.

ELASTIC STOP NUT CORPORATION OF AMERICA

2330 Vauxhall Road, Union, New Jersey

Elastic Stop Nuts with the famous red collar are another ESNA product

ESNA

Somebody ought to speak sharply to Nature

THERE'S a lot of loose talk these days about profits, attacking them as though they were evil.

The very existence of the world depends on profits; the *improvement* of the world depends on *big* profits. A farmer plants one potato and usually gets back 15. Even allowing for all his costs, that's more than 1000% profit! He plants one pound of corn and gets back 336 pounds—that's 33,600% profit. These are big profits. Is that bad?

Should the farmer be scorned as anti-social? Should his "excess" profit (whatever that is) be taken away from him? Should he be told that from now on he must limit his "profit" to, say, 6%?

To legislate against profits is as silly as to legislate against things growing.

WARNER & SWASEY
Cleveland
Machine Tools
Textile
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Warner & Swasey is always interested in talking future opportunities to young men of ability and character. Write Charles Ufford.

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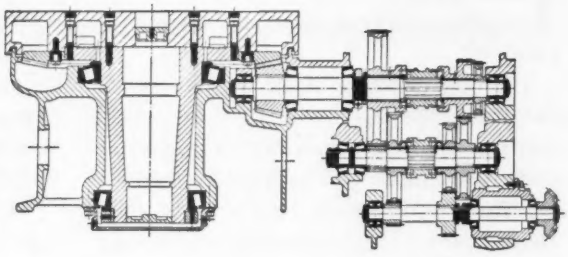

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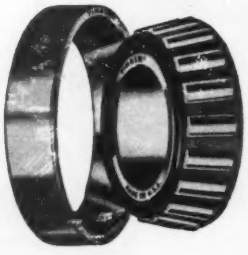

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from the editor's notebook

Room for Improvement

As another term gets under way most of us are striving to "do better," but is this also true in our student government? Possibly some minor progress is being made toward improving our student government, though much more could and should be done to make it better represent the students and better serve their interests.

Our present student government is largely ineffective because it isn't adequately informed about student opinion. Understandably, it can't serve the students if it doesn't know what they want. Many representatives of this government claim that it is up to the students to make their opinions known to their representatives. However, this isn't completely true because it is also the duty of an elected representative to know the wishes of his constituents.

Consequently, an effort should be made by our student government and our student representatives to become better informed about the student body's attitude toward various issues. It has made little effort in this direction with one exception, which was the investigation made last December on the issue of discriminatory clauses in the constitutions in a number of student organizations. Some other attempts have been made in the past by our student government to get in touch with student opinion without much success. For example, the Student Government Investigating Committee, whose purpose was to find ways of improving the student government, failed to produce as many proposed changes as it certainly could have if it had made a genuine effort to find out what kind of changes the student body would like to have in its government.

This committee failed to suggest several ways in which the government can be improved and made more truly representative. The committee, however, did make one excellent suggestion which was to eliminate the present system whereby only seniors vote for the president of the student government. Unfortunately this proposal was rejected last month by the Institute Committee, indicating that the present student government is satisfied with the status quo and unwilling to make changes that will make it a better government.

Nevertheless, there are several changes that could be made to achieve a genuinely representative government. One of these changes would be to alter the amount of influence various activities have on the student government. Several organizations, such as our publications, each of which represents about fifty students, now have the same voice in the student government as much larger student groups, such as the Athletic Association. Not only should the relative influence of various activities be altered but also their combined influence should be reduced if our student government is to fairly represent all the students. Many students who do not actively belong to an activity now have a smaller voice in the government than those who do. A reorganization of our present system in consideration of this situation would result in a truly representative government.

Also changing the present system of electing representatives would encourage greater student participation and interest. One way of doing this would be to require candidates to carry on an active campaign and to publicize the election and election issues sufficiently to arouse interest.

Let us hope that our student government will shake itself loose from its past history and make a resolute effort to become more representative and more closely informed about student opinion. H. J.

The Able bomb
at Bikini

the effects of atomic weapons

By Raymond Archambault, '56

Photographs: courtesy McGraw-Hill Book Company

Today it is a good thing to take time out every so often to get a better perspective of the future. Yet when we do, many of us are frightened by what we see. Just what are the problems that confront us? The answer to this question includes many factors that are of vital importance and continual concern to all of us.

One of the ever-present problems we face is the possibility of an atomic war. Unpleasant a prospect as it may be, we must not be reluctant to keep our senses alert and to investigate all the possible dangers that would accompany an atomic war, as well as all the preventive measures that could be taken to avoid or counteract these dangers.

It has been said that what we don't know won't hurt us. It is my belief that this is one case where the statement proves to be an absolute falsehood. When we're afraid of the dark what do we do? Some of us may turn and run; others will try to turn on a light so we can see whether there actually is something to fear. If we discover the presence of danger, then we do our best to avoid it or counteract it for our own protection.

The first atomic explosion took place at 5:30 a.m. on July 16, 1945, over the desert lands of New Mexico. Its dazzling burst of light was brighter than the noonday sun, its heat melted the desert sand and rocks and flowed them together. A great volcano of dust and debris churned thousands of feet skyward.

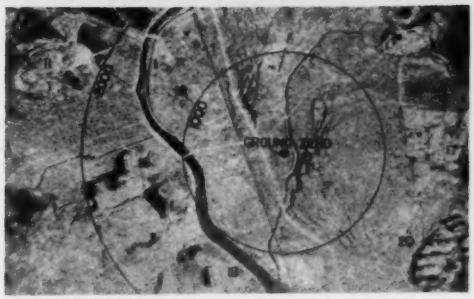
Soon afterward, Hiroshima and Nagasaki fell victim to the destructive powers of this atomic bomb. It laid these cities in utter devastation. Buildings were crumbled as though they were of sand, and steel frames were twisted like candy. For miles around, all combustible materials were set aflame by the tremendous heat of the blast. Thousands of people were killed instantly; many succumbed later from burns and radioactive contamination. Still others survived, fated to go through life maimed and scarred as never before imagined. It is with the effects of such a blast that we will be concerned here.

A *nominal* atomic bomb, similar to those used at Hiroshima and Nagasaki, has an energy release equiva-

Below: **Ground zero at Nagasaki before and after the atomic bomb explosion; 1,000 feet circles are shown.**

Upper right: **Residential areas at Nagasaki shielded by hills (bare area in foreground is a firebreak).**

Lower right: **Similar residential area, not shielded, reduced to rubble. Roadway was cleared of debris before the photograph was taken.**



the effects of atomic weapons

lent to that of approximately 20,000 tons of TNT. Further energy equivalents are:

2×10^{13} calories
8.4×10^{20} ergs
6.2×10^{13} foot-pounds
2.3×10^{7} kilowatt-hours

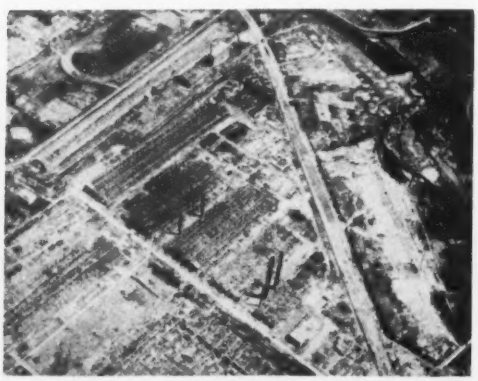
It is of interest to add that it is also equivalent to about 7,000 tons of coal and to the daily output of Hoover Dam.

However, we should note that, although the energy released in fission is very impressive, it is relatively small compared with the energies involved in the forces of nature. For example, it is about the same as the energy of the sun's rays falling on two square miles of ground during an average day, or to that released in a moderate rainstorm producing a quarter of an inch of precipitation over Washington, D. C. A strong earthquake involves almost as much energy as would be supplied by a million atomic bombs of the type under consideration. Yet, with such destructive power at our own and our enemies' disposal, it is wise to investigate all possible precautions that can be followed to insure human protection from an atomic explosion.

To better understand what can be done in the way of defensive measures, let us consider what takes place when an atom bomb explodes. Fundamentally, any explosion involves the sudden release of a large amount of energy in a very short period of time. The difference between a chemical explosion, say of TNT, and an atomic explosion lies in that the former consists of an unstable compound, the atoms of which rearrange themselves during the explosion with a liberation of energy; while in the latter, rearrangement occurs not only among the atoms, but also among the extremely small particles of the nuclei of the atoms.

Now these nuclei consist of positively charged *protons* and electrically neutral *neutrons*, the masses of which are very nearly the same. For this reason and others they are often referred to by the general term *nucleon*. Hence we may describe an atomic explosion as the result of a particular nuclear reaction associated with the rearrangement of the constituent nucleons of a suitable atomic nucleus. In simpler terms this means an atomic explosion depends on very special conditions. Not all nuclear reactions can lead to explosions. An unstable radioactive isotope is needed for the type of reaction employed in the atomic bomb.

A detonated atomic bomb appears after a few millionths of a second as a luminous sphere called the *ball of fire*. At this instant its temperature is about



(*Left*) General view of area of destruction of engineering factory, about 5,000 feet from ground zero, showing smokestacks still standing.

(*Below, left*) The patient's skin is burned in a pattern corresponding to the dark portions of a kimono worn at the time of the explosion.

(*Below*) Reinforced-concrete frame building, 5,900 feet from ground zero, showing crushing of concrete panel walls on side facing the explosion.

300,000° C. and its luminosity from a distance of 10,000 yards is approximately 100 times that of the sun as seen at the earth's surface. This ball of fire reaches a maximum radius of 450 feet within less than a second. So we see that unless the bomb is detonated less than 450 feet above the surface, the ball of fire actually will not touch the ground. This is accompanied by a shock wave which at first coincides with the surface of the ball of fire, but which soon advances more rapidly. It is therefore obvious that energy may be transported faster by the shock wave than by radiation.

Since, in atomic fission, most of the energy is released in the form of heat, it is here that we may expect to find the greatest source of harm. Indeed, the greatest damage to structures is caused almost instantaneously by the heat of the blast and its subsequent shock wave.

Danger to human life, aside from heat and the pressure of the shock wave, may stem from direct exposure to harmful radioactivity (such as gamma rays and neutrons), or from contact with radioactive materials and residue left by the blast. If the bomb is detonated less than 450 feet above the surface, it will lift skyward material which will eventually fall contaminated back to earth. However, if the explosion occurs high enough above the surface, this contamination is hardly sufficient to constitute a serious hazard. But, as a safety measure, one should take care not to venture into the area of an atom blast too soon after the explosion occurs.

Mushroom cloud attaining a height of five miles after an air explosion. The ice cap or scarf cloud at the top consists of myriads of small ice crystals; the gases above the mushroom expand and are consequently cooled, thus causing water vapor in the atmosphere to be converted to ice.

Following an atomic explosion, water and food supplies are apt to become contaminated and should not be used until it has been definitely determined whether they are free from such contamination. Properly covered foods should undergo little or no contamination. The same will be true of canned goods or any materials in impervious, dustproof wrappings. There appears to be no feasible means for salvaging unprotected food, either in the home, store or fields, which has become radioactively contaminated.

Investigating the effects of the atomic bomb on structures in Japan, we find that the intense heat and shock wave did the greatest harm. The essential features of a shock wave are an abrupt rise in pressure, followed by a gradually decreasing pressure lasting about a second, and then a suction phase characterized by a decrease below atmospheric which lasts for several seconds. Accompanying these pressure changes are intense winds which exert forces on structures for a relatively long period of time after the shock passes. The ability of a building to withstand the shock depends mainly upon its strength, somewhat upon its shape, and upon many other factors such as the number of openings through the buildings which can serve to relieve the pressure on the outside walls.

An important difference between the effects of an

Light steel-frame building, 1,800 feet from ground zero. Corrugated iron roof and wall sheathing were stripped by the blast, and the combustible contents destroyed by fire.

The stern deck of the U.S.S. *Nevada*, within 2,000 feet of surface zero, damaged by the air burst at Bikini.

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the effects of atomic weapons

atomic bomb blast and one due to a conventional, high-explosive bomb lies in a unique destruction feature of the former called *mass distortion* of buildings. An ordinary explosion will usually damage only part of a structure, but the atomic blast can engulf and flatten whole buildings. Wooden structures, yielding easily to the force of the shock, tend to ignite and burn immediately from the intense heat of the blast, while structures of reinforced concrete withstand the shock much better. Damage to the latter is affected also by such factors as the angle of incidence of the shock wave with the side of the building.

From the observations made in Japan it is possible to draw some conclusions relative to the blast damage to be expected at various distances from ground zero for an air burst of a nominal atomic bomb:

(a) Virtually complete destruction to a radius of ½ a mile.
(b) Severe damage (major structural collapse) will occur to a radius of at least 1 mile.
(c) Moderate and partial damage (rendering structures wholly or partially useless until repaired) will occur from a radius of 1⅝ miles to 2 miles.
(d) Beyond 2 miles, only light damage (plaster and window breakage) will occur.

These effects may vary slightly with conditions, but for the most part are to be expected. Some exceptions were found to be due, to a certain degree, to protection afforded by shielding. The general Japanese experience provides support for the view that the effect of one building in shielding another one would be small. There was some slight evidence of such shielding in Nagasaki, but in general the shielding of one building by another was not appreciable.

One striking example of shielding, however, was provided by a hill in Nagasaki. Here, buildings of European type, protected by this hill, suffered only light damage, mainly to plaster and windows. At the same distance from ground zero, in another direction and unshielded, the destruction was considerably greater, resulting in moderately severe damage.

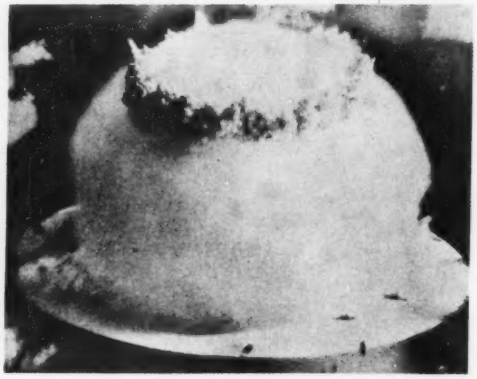
In Japan, certain buildings were designed to be earthquake resistant, which probably made them stronger than their counterparts in the United States, while other construction was undoubtedly lighter than that in this country. However, contrary to popular conceptions concerning the flimsy characteristics of Japanese residences, it is the considered opinion of a group of highly qualified architects and engineers who surveyed the atomic bomb damage that the resistance to blast of American residences, in general, would not be appreciably different from those in Nagasaki.

Considering shielding with regard to the human body, it is a recorded fact that light-colored, loose-fitting clothing gives many times the protection from thermal (heat) radiation than does dark or tight-fitting clothing. On the whole, at equal distances from the blast, garments afforded protection from thermal radiation varying directly with the thickness of the cloth layers. In most instances, skin burns appeared to be intensified where contact with dark clothing took place. The darker material apparently absorbed and transmitted the ill-effects of thermal radiation with extreme readiness, whereas the reflecting qualities of the light-colored materials prevented these burning effects in the same degree.

The explosion of an atomic bomb is accompanied by the emission of nuclear radiations consisting of gamma rays, neutrons, beta particles (electrons), and a small proportion of alpha particles. Since the range of alpha and beta particles is so small as to be negligible in the initial radiations, we will not consider them here. Both gamma rays and neutrons, however, have considerable penetrating power and can produce harmful effects on living organisms. They are, in fact, responsible for a great part of observed serious after-effects.

There are many ways of shielding against gamma rays and neutrons, whose penetrating power diminishes rapidly with an increase in distance from the point of

The slick, due to the shock wave, can be seen after the underwater explosion at Bikini. Note the target vessels.



emission. For example, at a distance of five-sixths of a mile, a wall of concrete two inches thick would prevent the passing of these harmful rays. Anyone in an underground shelter, subway, or basement will receive ample protection from these rays in most cases. The basement of a skyscraper, shielded by several stories having an accumulated thickness of three feet of concrete and even less of steel, will provide complete protection from radioactive rays, even if the explosion takes place directly above the building.

Still we always have the danger of lingering radioactivity, which must be dealt with in as quick and efficient a manner as possible. There are essentially three ways to minimize the hazards associated with radioactive contamination:

(1) Complete disposal by burial deep underground, or at sea.
(2) Allowing the radioactivity to die with time.
(3) Attempting to decontaminate the material.

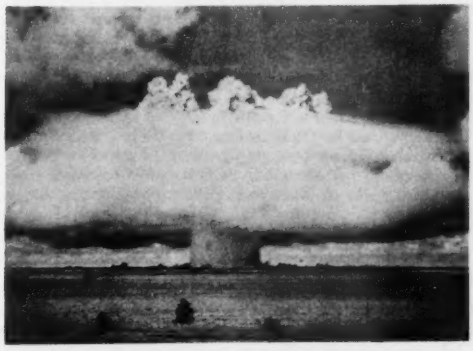
The particular method adopted in any case will depend on circumstances. Large structures could not be easily disposed of; and where the cost of decontamination would be too great, burial would be the most economical plan.

Except where a porous material has absorbed a radioactive liquid or where radioactive material has found its way into the water supply, contamination will be largely a surface phenomenon. For surface removal of contaminating radioactivity from the target vessels used in the Bikini tests, abrasive methods such as wet sandblasting were employed most successfully. Chemical means of removal can also be designed for each type of surface, and lightly held contamination, such as dust, may be simply vacuumed off.

The decontamination of personnel who have come into contact with radioactive material is, of course, a primary requirement. Clothing should be disposed of in a manner to avoid spreading the contamination. Vigorous cleansing with soap and water will remove activity from the skin about as well as any other method. However, due care should be exercised to avoid abrasion and possible consequent infection.

So we see that, while the dangers associated with an atomic explosion are numerous and real, there are adequate means of counteracting them. As they are more completely understood, new and better methods will undoubtedly be devised. One great means of protection is to know what dangers exist, so that when called upon, we may think and act soberly and without panic.

Formation of the column in the underwater explosion, demonstrating the massive lifting force of the bomb. Note the target vessels.



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The economics of Flexible Shafts
Courtesy Bell Aircraft Co., Buffalo, N. Y.

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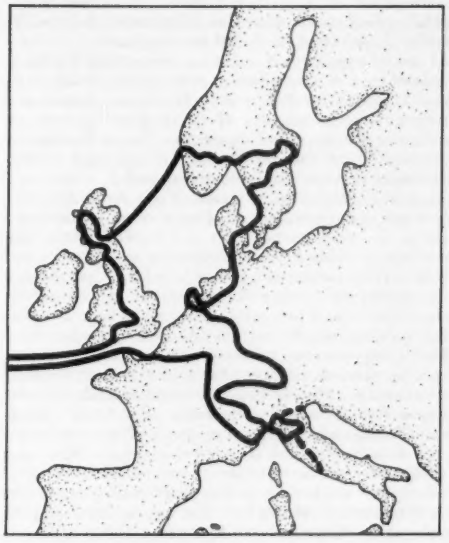


INDUSTRIAL TOUR OF EUROPE, 1952

During the summer of 1952, Professor Brown organized and conducted the Eighth Industrial Tour of Europe sponsored by the School of Industrial Management at the Massachusetts Institute of Technology.

On this tour a group of twelve students spent two and one-half months in Europe for the primary purpose of visiting over fifty industrial plants. The plants represented a wide cross section of industry, and within each country, industries unique to the area were studied.

Maximum opportunity was provided to meet the top members of European management and to join in the exploration and resolution of management problems. In addition, some of the most advanced European research developments were observed.

europe and the dynamic nature of industry

By Professor Carroll J. Brown

Exploration of industrial problems in the western nations at mid-century leads the observer to a basic conclusion in regard to the importance of industry. Economic strength, social progress, and military power appear in the contemporary world almost exclusively in highly industrialized societies. Today national well-being results from production so successfully organized that surpluses beyond minimum food and shelter requirements arise and may be devoted to developing national strength.

During the past two generations, industrialization has been a potent factor in bringing about a shift in the balance of national strength throughout the world. Until 1914, Europe was the undisputed center of world power and leadership; all other parts of the world were, so to speak, fringes of the European world. Today Europe is no longer the center of world power. Instead there are two centers, both of which are outside Europe.

The United States did not seek its present power; world leadership has never been a motivating element in American life. Nevertheless, much of the remaining free world looks to us to supply responsible leadership — an inherent obligation of the powerful. Obviously we have not intentionally prepared to play the role which history has given us. Thus we find ourselves immersed in international affairs with few traditions to guide us.

Since American technological skills have brought this nation to a position of world leadership, we should examine our technology for the purpose of finding in it those elements which we may use in improving ourselves and in forming closer, friendlier and more helpful ties with other nations. As we consider American industry in comparison with European industrial patterns, three major elements appear:

(1) National influences need not be the essential factors in the development of technological achievement.
(2) Attitudes are decisive elements in industrial achievement.
(3) Decentralization of responsibility is the concept which most strikingly distinguishes the American form of industrial organization.

In nineteenth century thought, superiority of skill in industrial production was attributed to certain western nations. British exports of textiles and fabricated metals to primitive cultures insured vast accumulations of profit and power. German, French and Dutch products poured into their respective colonial areas to fill demands which the colonies could not meet by their own production. It was assumed that technological skill was a characteristic of the European and later of the American mind.

At mid-twentieth century we find great change in this situation. The economies which once demanded consumer goods now demand capital goods and training which will lead to independent production. Textile technology, one of the earliest to pass from hand to power production, illustrates the change. As India absorbed the products of British mills, its hand looms became idle. The importation of textile machinery and operational training was the next step in the industrialization pattern. Then came the reproduction by the Indians of the British machines. A future step for

India may be the development of new products and processes and the building of machines for their realization.

Many indications of this internationalizing process were seen by the members of the Massachusetts Institute of Technology's Industrial Tour of Europe in the summer of 1952.

In England we visited a world renowned textile university and heard much about the present status of textiles and textile machinery. The manufacture of textile machinery was early dominated by English production and later by English and United States production. Now we find many other countries producing their own equipment. The English and American export market for textile machinery in the Far East, for example, is rapidly being filled by Japanese and Indian machinery. The casual observer remarks that the English or Americans developed the textile machinery and that the other countries merely appropriated the designs. The fact is that we are observing one of the early stages in the pattern of industrial change described above.

In Germany we visited a famous manufacturer of cameras and other optical equipment. Here we learned that technological developments in the United States before the war had raised the quality of the American product to approximately that of the German. Now we find Japan emerging as a manufacturer of optical equipment comparable in quality to that of Germany or America. There is even some indication that the Japanese have not only duplicated the German and American optical products, but also that they have improved upon them.

In England we visited a leading manufacturer of jet engines and aircraft for both military and commercial use. Here again we saw an example of what may be called the internationalizing of technology. The developmental period from idea to product is probably longer in the aircraft industry than in most others, but even here we learned how quickly products could be reproduced. The Japanese "Zero" engine as well as the Russian "MIG" engine was developed in Great Britain. However, both Japan and Russia have been able to produce them in quantities great enough to inflict considerable damage on enemy forces. Any new developments in product or process by this English concern can be reproduced elsewhere within a few years, if not a few months.

Thus we find that any group of people can operate most machines, turn out most products on them, repair them when they break down, and duplicate them if necessary. In addition, some groups can show some ingenuity of their own and improve on the products of others. In this day of labor specialization and mechanization, even the most unskilled of workers can, with suitable managerial supervision, produce the most complicated and delicate of products.

Although it is apparent that nationality is not an essential element in the achievement of industrial skills and that industrial skills may be acquired by any national group which is strongly motivated to acquire them, we must not forget that industrialization is a process of uneven dynamic quality. The rate at which such development takes place varies from country to country and from time to time. Some nations move slowly from handcraft skills to power production; others, such as Japan, move with great rapidity. Factors influencing rates of national development would include war or threat of war, discovery and development of raw materials, continuity or discontinuity of history, attitudes toward change, and the quality and number of leaders. Over the years certain countries tend to push ahead and explore new industrial fields; then, for one reason or another, they tend to "hold the line," and their energies are often directed to other areas such as political, spiritual, or social development.

It would appear that some countries tend for long periods of time to be leaders in new developments (e.g. England) and other followers. The time periods are of necessity great because of the lengthy process of education and training necessary for a people to achieve leadership in the industrial world as opposed to the much easier process of following the leader.

England achieved new levels of industrial development a century ago in a period of relative world stability. There is no question but that the United States has moved ahead of her in many industrial areas during the past twenty-five years in a period of relative instability.

It should be further noted that in the twentieth century the rate of industrial change has been tremendously accelerated. Here at the Massachusetts Institute of Technology we may see many examples of these ever-increasing rates of change. Some of the more obvious illustrations are the old and new wind tunnels, the old and new Van de Graaff generators. For several thousands of years there had been no great advance in man's ability to produce and to control energy. Man was working with one horsepower, or more recently several hundred and then several thousand horsepower; but with the control of nuclear energy within the past decade, man thinks of working with millions of horsepower per pound of atomic fuel.

In England, Norway and Sweden we find many indications of acceleration in research. Several northern European laboratories are carrying on intensive research in problems of vibration, strain, and creep. New product developments are requiring much of this research, e.g. special steel for jet blades with properties to withstand high temperatures.

In the American automobile industry the concept of the annual model has for many years been established. In addition to the annual decorative repositioning of chrome, there are technological improvements in such areas as additional safety, more riding comfort, greater speed or ease of driving. It has been said that after visiting the advanced design rooms of one of our automobile companies, a member of a European Productivity Team remarked that he could not understand why he had been permitted to observe the new preproduction model. He was told that he could copy the model because it would be obsolete before he could get it into production.

Until recently, fifty years was the accepted time unit for establishing depreciation rates on equipment. At the present time much of the more specialized equipment may well be obsolete at the end of five years if not before. This is not meant to imply that we are now making equipment of lower quality but rather that changes are taking place so rapidly that equipment frequently becomes obsolete long before it has become worn out. Modern industry affords many illustrations of ever-increasing rates of change and obsolescence.

Existing industrial time lags or gaps between nations now tend to increase because of the increasing rate of change and progress of the advanced industrial economies. The industrial time lag between nations is no less important than the cultural time lag, and it is a major factor to be considered in any discussion of economic, political, or industrial problems.

Why has American technology been able to create those surpluses earlier referred to? The American successes appear to have resulted not only from the tangible elements discussed above, but also from certain intangibles. Among these are the attitudes of the people.

Certain attitudes are created by the circumstances of history. The very character of the Europeans who ventured into the American wilderness was a factor which conditioned an attitude of optimism. Europeans settling in America looked to the future and away from the past. Whether the immigrants were pioneers, the vanquished or the poor, they looked with great expectation to the future. As Americans, geographically removed from European difficulties, they were free to evolve foresight and optimism. This belief in an improved future became a vitally important attitude in the rapid colonization and industrialization of the United States — a record of achievement unparalleled in world history.

Frontier conditions forced the settlers to be self-sufficient, adaptable, and inventive. The qualities developed in the frontier culture were later carried over into industry.

Another important factor in the development of American industry is the fact that in our early national period the expansion of population and beginnings of American industry coincided roughly with the Industrial Revolution. Industries founded in America did not have to break down established habits of thought or earlier patterns of production. In America it was seldom necessary to re-educate workers trained in pre-Industrial Revolution crafts. A new continent for settlement, a new and independent government, new concepts of the use of machinery — these factors form a syndrome of forces which were to produce the modern America.

The favorable conditions in which industry developed led to the great successes which fired the American imagination. One success created the situation which produced other successes; the American became conditioned to the idea that he could achieve whatever he set himself to accomplish. The entrepreneur, the administrator, and the worker all followed the tradition of success, all attacked new problems with a positive expectation of success and a belief in their ability to achieve it.

"Nothing is impossible for Americans" is a cliché overused to the point of absurdity, but one cannot deny that it represents an attitude that has been a factor in building achievement on many levels, a factor in the subconscious perhaps, but potent nevertheless.

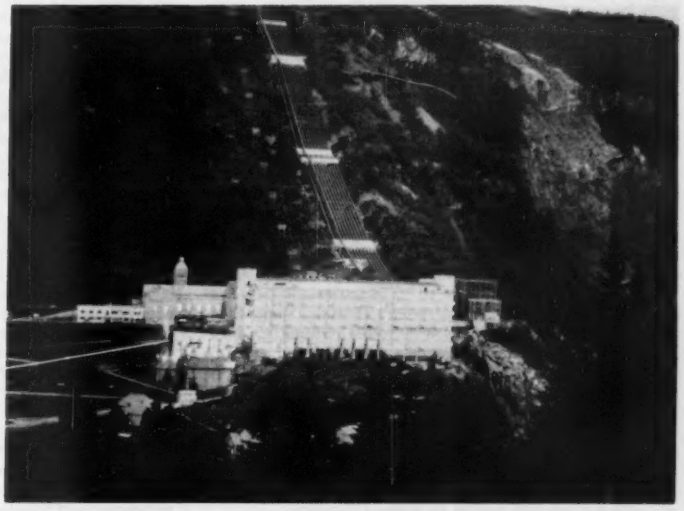
We find that attitudes are decisive factors of influence in American industry, and that most of the attitudes center in the individual and his belief in himself. The attitude of American industry toward history is forward looking. Industry expects to continue in the future to benefit from those dynamic and expansive processes which have constituted American history.

We find the European, on the other hand, thinking in terms of the past. His historical experiences bind him to conservative procedures and a stable way of existence; but recent history is forcing him to admit the need for change without providing him with the optimistic outlook necessary to motivate it. His faith in the possibility of progress has been shaken; his power and leadership have been weakened. Gradually but reluctantly he has become aware of changes in technical progress which disrupt his former concepts of social, economic and political stability. On the other hand, we find the United States brought up on the idea of change leading to improvement, looking ahead to the future optimistically and expanding its industries at ever-increasing rates.

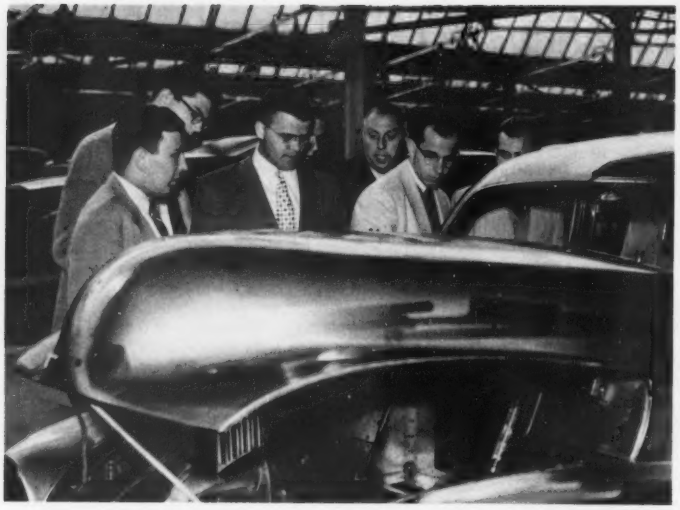
Whatever may be the motivation for industrialization of twentieth century national groups, it is apparent that the United States is in a position to encourage the acceleration of industrialization of other countries and that self-interest dictates the giving of such help. The contrasts between the highly industrialized modern country and the medievally backward country are so great that no world social system can be devised which would permit such contrasts to exist side by side for any extended period of time.

The United States needs Europe's help whether one believes in the traditional "balance of power" concept, in containment of Communism, or in counteroffensive tactics. We cannot afford to turn our backs on European immobility, conservatism and pessimism any more than we can ignore the same conditions at home in industry or government.

Since we find that the material factors in the industrial process may be reproduced by non-industrialized cultures, we now ask what special items of our system



Night Scene,
Heavy Water Plant,
Norsk Hydro Company,
Rjukan, Norway



Morris Motors Limited, Cars Branch, Oxford, England

may we contribute to nations now in the process of moving from craft levels of production to a power-production economy. It is clear that attitudes are a major factor in the success of American industry. Can we share with other nations those attitudes which have conditioned our industrial thinking?

Obviously we cannot re-create for other peoples those conditions which influenced our national beginnings and expansion. Nor can we pass on to other nations the psychology of success which has so largely influenced our technological advance. The principal intangible factor which we are able to transfer to others is our attitude toward the individual.

It is true that historically both English and French thought have emphasized the importance of the individual. However, in the new technological society, concepts of individual freedom have changed. For example, today a man is free to live twenty miles from his work, yet dine at home each evening. He is not free to drive according to his momentary whim; instead he must follow patterns of direction and speed already worked out for the control of mass movement. He is free in traffic only when he and other drivers conform. For his larger freedom, to live where he chooses, a freedom which technology has given him, he gives up the ancient freedom of driving his horse as fast as he chooses.

The reconciliation of the old ideas of freedom with the new controls, made necessary by technological progress, has been a major development in the twentieth century. In the industrial world, one of the most important problems is how to give the employees the status of free and responsible men. It would seem that the most significant change in America has taken place in connection with the employee's status. The question is one of giving a man a feeling of freedom and responsibility in a highly complicated and highly organized industrial order. Considerable progress has been made in this direction in America during the past decade, and from our observations in Europe it would seem that the individual's importance has been largely unrecognized in Europe. Recently, Marshall Plan Aid and other programs began to make it known.

In America the worker's freedom and responsibility and his sharing in the shaping of the direction and policy-making of his company have been secured by many different devices. Among these devices are profit sharing, bonuses, incentives based on productivity, stock participation programs, employee and executive development programs, and decentralization of responsibility. These have now come to be a standard part of American industrial practice. Whenever possible, our Economic Cooperation Administration and more recently the Mutual Security Agency authorities, are showing these new directions to Europeans. In some cases, granting aid has been practically dependent upon management's willingness to accept these new concepts and to try to improve the worker's status.

Among the devices mentioned as contributing to the employee's sense of status, the most important is decentralization. Decentralization as here used is the division and distribution of responsibility. Essentially it is the process of pushing decision-making down to the lowest possible level, the level at which the facts are collected. There have been and are being developed many control techniques for the management of decentralized organizations where much responsibility and authority have been delegated to the lower structural levels. We can see that such practices not only permit efficient operation of large organizations but also permit the top administrators to spend more time on determination of objectives, long range plans, and major policies. But, possibly more important, decentralization of responsibility permits the man in the low structural level — the employee — to take part in the actual running of the company. It gives him a chance to participate, to be something more than a mechanical man. It gives him a chance to use his head as well as his back. It gives him a feeling of status, of responsibility and of freedom, even though such freedom may be in a limited area. We see even in big industrial combines a tendency to build little independent units, little responsibility centers within which the employee is the proprietor. This situation in itself emphasizes the importance of individuals and produces in them a feeling of independence and freedom.

As we examine European business patterns, we note the absence of several factors which made successful decentralization of responsibility possible in America. Among these are executive development programs, control techniques in accounting, division of responsibility into easily managed units. A further element which impedes the progress of decentralization in the older industrial systems is the traditional attitude of paternalism.

The executive development program in America trains men for positions of responsibility. It further aims to develop a type of executive mind which can adapt itself to new problems and processes, a mind which will not become obsolete. In addition to providing the employee with increased status, the training program in the long run will simplify the superior's job in that the subordinate is in a better position to assume greater and greater segments of his superior's responsibility.

Hereditary ownership of many European companies has for generations produced a class of "born" managers, men whose place at a manager's desk was determined by birth. These men naturally are slow to encourage the rise of professional managers as their competitors.

In observing European industry one notes that industrial training programs are planned almost exclusively for the development of craft or technical skills. Such programs are designed primarily to teach the employee to be a better machine operator, welder, or electrician; but they do not attempt to teach the employee to be a better manager.

Many of the European plants we visited were proud of their craft training programs. In plant after plant, in England, Scandinavia, and on the continent, we found the companies assuming a tremendous burden of shop training for their people. For example, in one of the large English electrical companies we found six hundred boys from the ages of sixteen to nineteen spending half a day in apprentice school and half a day in production work. In addition there were three hundred fifteen-year-olds in trade shops where they were experimenting with the various trades before selecting one. This plant as well as many of the others had its own apprentice training shop. In Scandinavia, a munitions plant had its own apprentice training program in which a boy would spend three years prior to becoming a qualified machinist.

The introduction of executive development programs into European industry would result in the eventual appearance of new dynamic forces in the field of management. Such programs will develop professionally trained executives who will bring new brains and new attitudes to the problems of management. Perhaps the most far reaching consequence of such programs will be the creation of the intellectual and emotional attitudes which permit successful decentralization of responsibility.

A second factor which will favor decentralization is the introduction of techniques which permit management to coordinate and control the activities of decentralized units. The most comprehensive of these techniques is fixed and variable budgetary control. A description of this technique as an instrument for "delegation of authority, co-ordination of activities, and control of efficiency" was presented by Dr. Abram Mey at the International Management Congress at Brussels, July 1951, and is the subject of Section Seven of the report of that meeting.

In the summer of 1952 we observed very few instances of the collection and use of cost data for control purposes. When such facts were collected they were used almost exclusively for historical purposes, evaluation and profit accounting.

Adoption by European industry of this control mechanism will undoubtedly permit greater delgation of responsibility. However, this technique suggested here as one of the methods by which decentralization may be facilitated, is likely to be ineffective in a static economy dominated by fixed markets and cartels.

The third factor noted above relating to successful decentralization of responsibility is the type of organization which permits division of responsibility into easily managed units. Basically there are three ways of partitioning responsibility: partition based upon function and partition based upon product or geographical factors. The functional type of organization is that structure in which the first level of delegation is by function, such as sales, finance, personnel, public relations, production or research. This type permits a high degree of specialization in a given function. The disadvantage of this structure lies in the difficulty of establishing independent responsibility centers.

The two remaining types of organization, those based upon product and geographical factors, allow the creation of independent responsibility centers. Within each center a person is given extensive freedom of action for which he is held accountable. The independent centers are in a sense competitive with each other, but between them is a high degree of cooperation. Such decentralization of responsibility promotes a desire in the individual for innovation and progress.

The observer of European industry notes extensive use of the functional type of organization. A shift to wider use of the product-geographical type structure would facilitate the development of new awareness of the value of the individual, an elevation of status, an emotional climate conducive to success. Building new structures of responsibility may be difficult, but the values to be gained are very great.

American industry has fostered individual freedom by developing individual responsibility centers at all structural levels in all areas of activity. It may well be that improvement in an individual's sense of responsibility in his working hours helps develop in him a sense of freedom in his political relationships — the attitude which makes democracy possible.

When we compare the industrial structure of the United States with those of other countries, we find that the success of our system appears to be associated with certain attitudes, among which individualism, freedom, and leadership are most significant. American industry can point to its many leaders at all levels, of large enterprise or small, and can say with conviction that by its delegation of responsibility, it develops men as leaders and not as "mass-men." This delegation of responsibility is one of industry's most important contributions to American life, and at the same time a vital factor in America's industrial supremacy.

Our dynamic industrial economy has made the United States a world power. We now find ourselves obligated to become world leaders. Perhaps our manifest destiny is to help other peoples acquire the technologies which have created our own great civilization. The elements in our technology which may help to advance the industrialization of other nations are centered in the American concept of freedom and importance of the individual. Freedom, historically our motivating force especially in religion and government, is now recognized as the significant element in our technology — an element which we must continue to use for our own development and for the creation of helpful ties with other nations.

particles from outer space

Cosmic Rays: Key to Elementary Particles

By Jerry Tiemann, '53

Cosmic rays as we observe them in the atmosphere contain electrons, photons, neutrons, protons, mesons of many descriptions, heavier nuclear fragments, such as alpha particles, and many other unexplained particles, such as the S-particle and the V-particle. At sea level there is a high energy cosmic ray particle crossing every square centimeter of the earth's surface on an average of about two times a minute. Approximately once a day one of these particles stops in each gram of material and decays into an electron of about fifty million electron volts energy and another undetectable particle. However, only the most penetrating particles ever get down to sea level. In order to observe the more highly interacting particles, one must go to very high altitudes. But even on the highest mountains, the majority of the particles observed are fragments of air nuclei, blasted apart by the primary particles coming from outer space. In order to observe the primaries, and to make measurements of their intensities, balloons must be used to get the apparatus above the atmosphere.

No one knows the origin of the primary particles. For a long time they were thought to come from the center of the earth. This was because a Geiger counter always counts faster near the ground. It was about ten years before this effect was traced to radioactive elements spread throughout the earth's crust. The fight raged on until balloon flight data showed that after the initial decrease, cosmic rays again increased in intensity the farther up the balloon was, and hence that the primaries come from outer space. Because of the fact that even balloons cannot get to the very top of the atmosphere, no one is sure of the exact nature of the primaries. By measuring the effects of the earth's magnetic field, it has been found that the primary particles are predominantly positive. This fact, together with the astronomically observed fact that interstellar space is filled with hydrogen gas, has led to the conclusion that the primary particles are protons, or hydrogen nuclei.

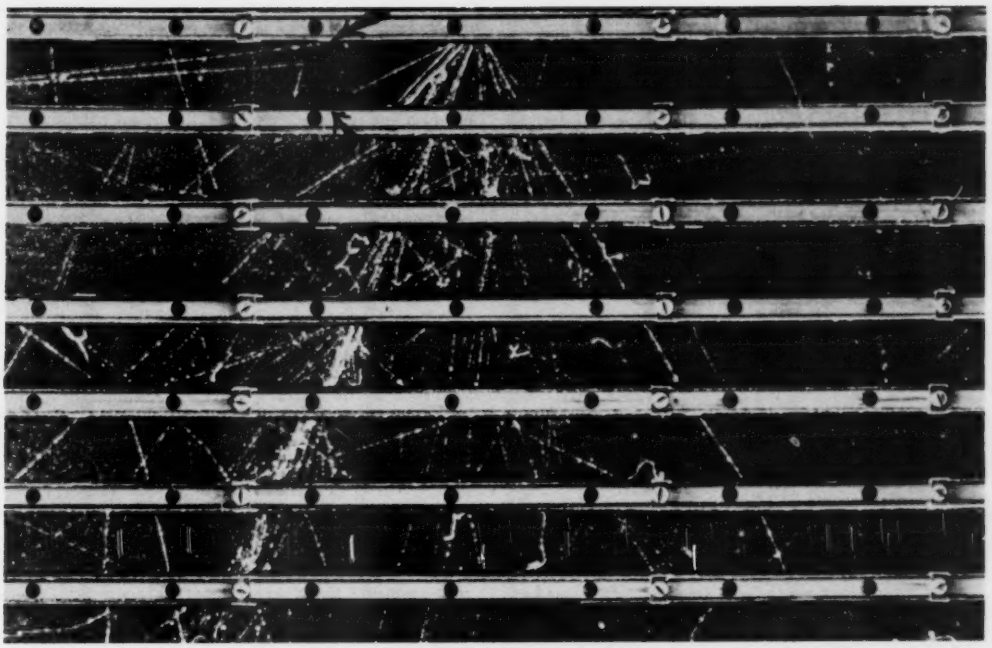
More puzzling than the nature of the primaries is the question of how they attain their tremendous energies. By measuring the total energy of the incident cosmic rays and dividing by the total number of incident particles, the average energy was found to be greater than ten billion electron volts. Occasionally primaries are observed with energies of 10^3 billion electron volts or more, and there seems to be no upper limit to the energy which a primary can have. There have been many attempts to explain how these protons attain these unheard-of energies. Some suggest that maybe there are large clouds of electrically charged particles which accelerate any protons which come near them. If a proton were expelled from a star which was receding from us, the star could turn the proton around. The proton could then approach us with a greater velocity than it formerly had. Others have suggested that since there is no static frame of reference in the universe, the protons should be coming and going with all momenta occurring with equal probability. Still others have proposed that the law of equipartition of energy, which holds for gases composed of both heavy and light particles, might still hold, at least to some degree, when the "gas" is composed of a mixture of stars and protons. If this is so, the stars and protons would tend toward the same kinetic energy relative to volts.

Which, if any, of these theories is true, only time will tell. Luckily, the usefulness of cosmic rays does not depend on an understanding of their nature or origin. Their usefulness lies in their high energy. They are energetic enough to initiate every known nuclear reaction as well as many which, although frequently observed, are as yet unexplained.

There are many different ways by which cosmic rays can dissipate their energy. The primaries most often suffer a collision with an air nucleus, which results in anywhere from two to ten or fifteen secondary particles. These secondary particles include all the known elementary particles, as well as many which do not fit into any of the theories which are presently available. The photons and electrons which are produced continue dissipating their energy by forming what is known as a cascade shower. The mechanism of this shower is as follows: When an electron undergoes a sudden deceleration, such as a collision with the nucleus of an atom, it radiates some of its energy in the form of a photon, or gamma ray. This photon can materialize into a pair of electrons, one negative and one positive. Each of these new electrons can radiate several more photons, and so forth, until the initial energy is divided among so many particles that the photons produced no longer have sufficient energy to materialize into a pair of electrons. At this point, the process continues by means of the Compton effect in the case of the photons, and by means of collision loss or ionization loss in the case of the electrons. The Compton effect is the process in which a photon loses some of its energy to one of the electrons in an atom. No new particles are created. There is merely a redistribution of the photon's energy between the photon and an electron. Ionization loss is undergone by all charged particles at all energies. In this process one or more of the outer electrons in an atom is barely dislodged by the particle moving past. The electron and ion float about for a while and eventually re-combine. Although only a very small portion of the energy is removed from the moving particle in this process, it is by far the most important one from our point of view. It is this process in which a trail of ions is left wherever the particle goes, that enables us to detect and measure the cosmic rays. The ions and electrons which appear along the path of the charged particle make this path visible in a cloud chamber. Similarly, it is this charge which discharges Geiger tubes and is measured in the ion chamber.

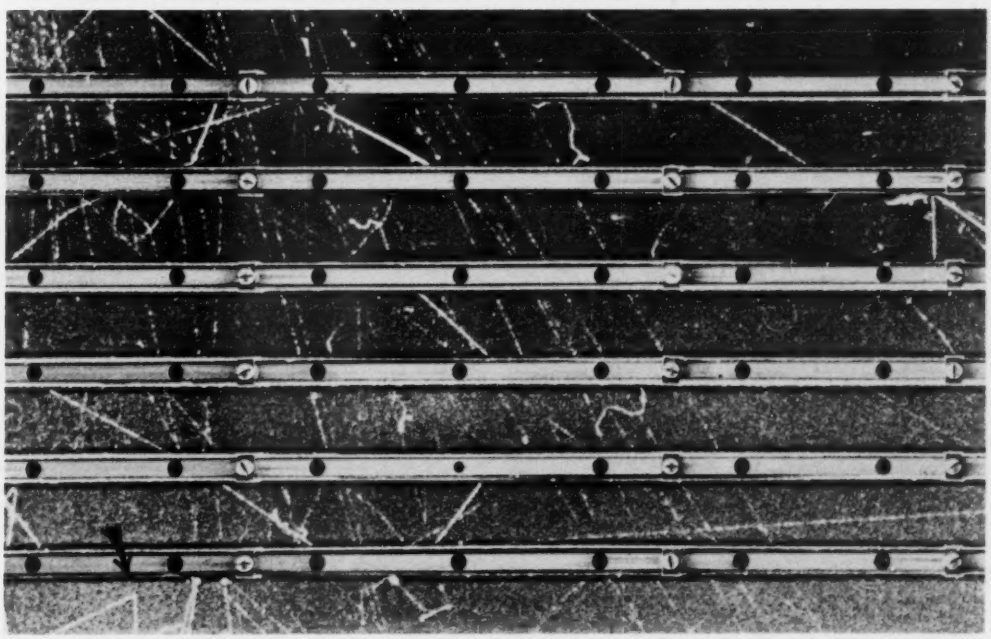
Most of the other secondary particles follow more or less the same sort of processes. Instead of radiation and materialization, they depend on further nuclear collisions for the dissipation of their energy.

Sometimes the protons and neutrons are captured



A high energy nuclear disintegration caused by a cosmic ray particle. Some of the electrons produced in this process form a small shower. A little to the left of the interaction a neutral V particle can be seen.

A very highly penetrating shower of mesons. At the lower left a V particle decays. The nature of this particle is one of the most interesting problems of modern physics.



by nuclei but do not cause the nucleus to fly apart. When this happens the residual nucleus can either become a radioactive isotope or a stable one. The transmutations to stable nuclei are not of any special interest, but some of the transitions to radioactive isotopes are extremely important. At the head of the list by far is the transition in which a cosmic ray neutron strikes a nitrogen atom in the air and ejects a proton. The resulting atom is carbon 14. This isotope decays back to the original nitrogen atom by giving off an electron. The half life of this reaction is 5,899 years. The reason this isotope is so important is that it enables paleontologists to measure the age of any organic compound. Plants, in their normal process of photosynthesis, remove carbon dioxide from the air and make sugars and other foods from it. They take in the radioactive carbon 14 along with the ordinary carbon dioxide in the atmosphere. By measuring the amount of radioactivity left in any carboniferous material, archeologists, geologists, and other investigators can determine when it was formed.

Some of the other secondary particles have more interesting methods of losing their energy. They are unstable by themselves, and are likely to break apart into two or three or more entirely different particles. The most famous of these, the π meson, is unfortunately the only one which is understood very well in theory. The π meson lives on the average about 10^{-8} seconds. At the end of this time, it becomes a μ meson. The μ meson is somewhat more stable and is a very highly penetrating particle. For this reason, it is the most frequently observed particle at sea level. The μ meson is also unstable, and at the end of about 10^{-6} seconds, on the average, it decays into the electron and the undetectable ray mentioned earlier.

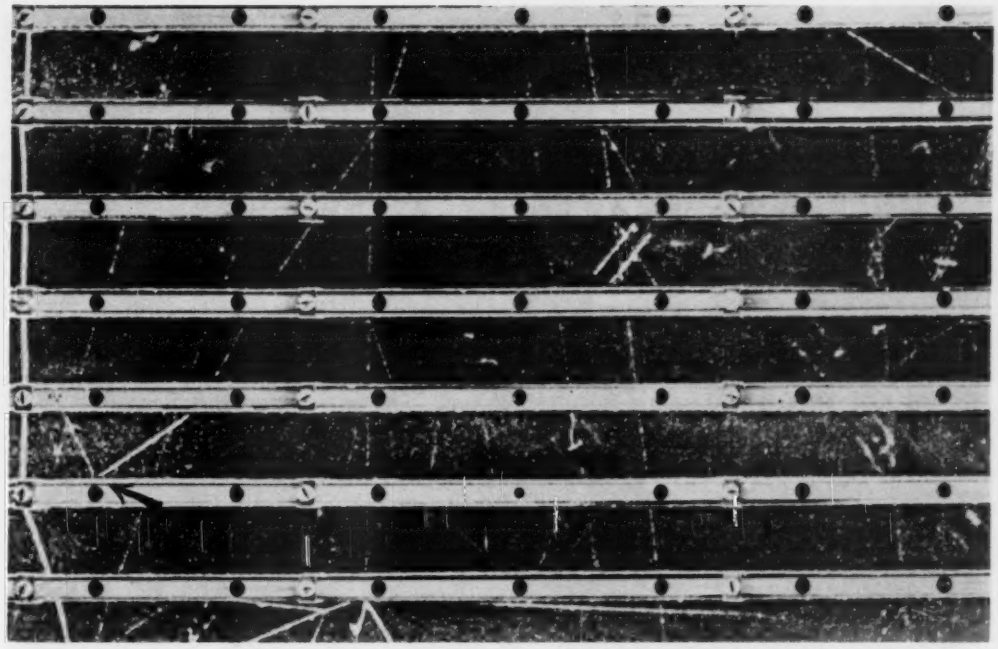
The π meson was predicted in 1935 by the Japanese physicist Yukawa on the basis of the large attractive forces which hold the nuclei of atoms together. Although it would be too difficult to go into the reasoning behind this prediction in detail, it is not hard to see why a particle with a definite mass is associated with every force field, no matter what kind it is. Every force field has some energy associated with it. According to the Theory of Relativity, this energy has a certain amount of mass associated with it, given by the formula $E = Mc^2$, where c is the velocity of light and M is the mass associated with the energy E. When the total amount of energy needed to start up the force between two nuclear particles is calculated, the mass associated with it turns out to be about two hundred electron masses. Two years later particles of about this mass were observed in cloud chamber photographs of cosmic rays.

There are several ways in which the mass of a particle can be determined from cloud chamber photographs. The most widely used is the method of scattering and range measurements. When a charged particle comes near the nucleus of a heavy atom, it will be repelled or attracted by it depending on the sign of the charge on the particle. This attraction or repulsion tends to change the direction of the path of the particle. Heavy or fast particles will go more or less straight through, while lighter or slow particles will be deflected through greater angles. This process of changing the direction of a particle is called scattering. By measuring the angle through which the particle is deflected, and by measuring the energy of the particle by means of the distance it travels, its mass can be determined with fair accuracy. By measuring this data on a large number of tracks which appear to be made by the same particle, the mass of the particle can be determined within a few per cent.

In order to observe as many scatterings as possible, cloud chambers are often built with many layers of lead in them. It is the purpose of the lead to deflect the particles, and it is the purpose of the space in between to allow the investigators to measure the direction of the particle's path. This is done by means of a stereoscopic camera placed in front of the cloud chamber.

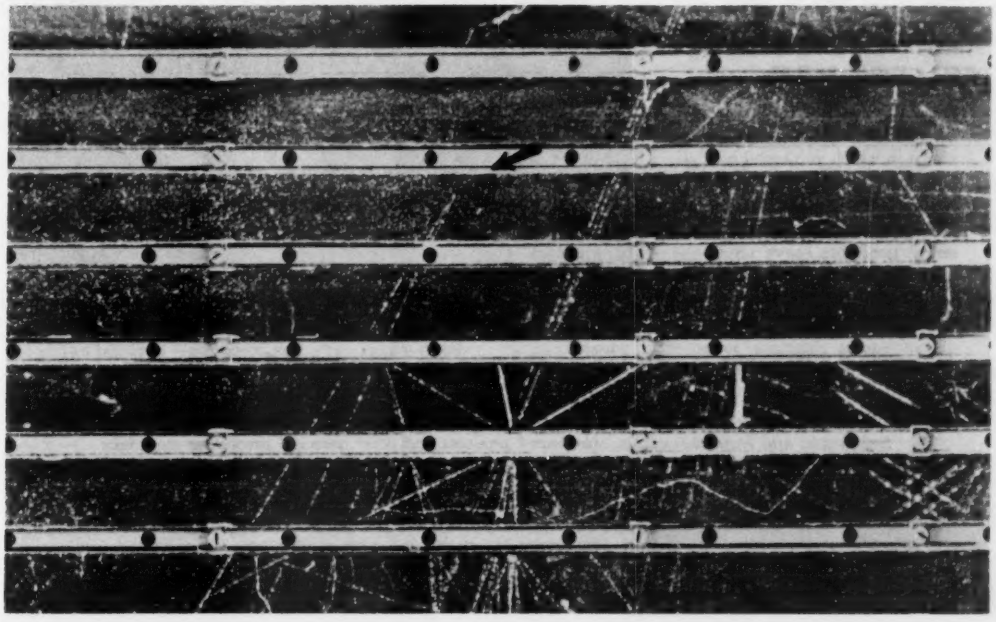
Although the successful operation of a cloud chamber is a very difficult feat, the theory of its operation is very simple. The cloud chamber in its normal state is filled with a gas, saturated with some vapor such as alcohol or water. When the cosmic ray event, which the researcher is interested in, comes along, the chamber is expanded by means of a moveable diaphragm in the back of the chamber. The resulting change in pressure causes the vapor to become supersaturated. This vapor will condense on any ions which are present in the chamber before anything else. For a while the chamber contains little vapor trails marking the exact paths of the cosmic ray particles. When the droplets have grown to a large enough diameter to be photographed, the lighting system is turned on and the cameras take the picture. On the basis of scattering and range measurements, the observed mass of the π meson agreed very well with the theoretically predicted mass. However, there seems to be a large number of particles in addition to the π mesons and the more familiar particles. There is a neutral particle which weighs about 2,200 electron masses and which decays into two charged particles, one with about 900 electron masses and one about 1,300 electron masses. Particles which decay in this way are called neutral V-particles, because their tracks look like an inverted "V" in a cloud chamber. The neutral particle leaves no ions, and so leaves no track. When it decays, however, both of the products are charged and hence leave a trail of ions. There are charged V-particles as well as neutral ones. These decay into a different charged particle plus a neutral one.

There are at least three different kinds of neutral V-particles, and probably as many charged ones. There are also several more stable particles about which we know nothing more than that they exist. For instance, there is the new S-particle (S for "stopped"). This particle is stable enough that it does not often decay in flight, but usually lasts long enough to come to rest. However, when it does come to the end of its life, its decay product has enough energy to traverse as many lead plates as it has been possible to get into a cloud chamber. It does not seem possible that all of these different particles are associated with their own particular types of forces. If they are, trying to fit them all into a consistent theory will be the work of many years. And if they aren't associated with any forces in nature, the problem of just exactly what they are associated with will be an equally difficult question. At any rate, if you have ever wondered whether physicists will eventually know everything there is to know about the universe, fear not; there will always be new cosmic ray particles which just refuse to fit in with the theories of the day.

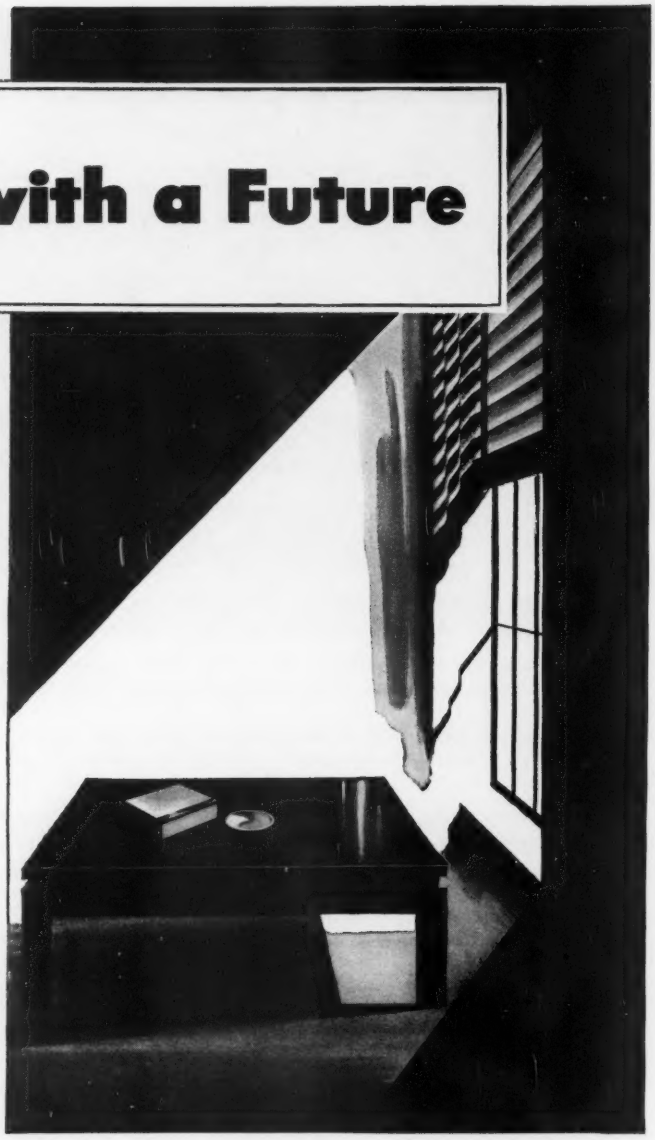


A meson decaying into an electron. The meson can be seen coming downward to the left. It is scattered extensively by the lead plates. The electron can be seen going back up again at the end of the track.

A shower of particles from a nuclear interaction. One of the particles, probably a Pi Meson, causes another nuclear event. Another is a neutral V particle which can be seen decaying right above the nuclear explosion.



Finish with a Future



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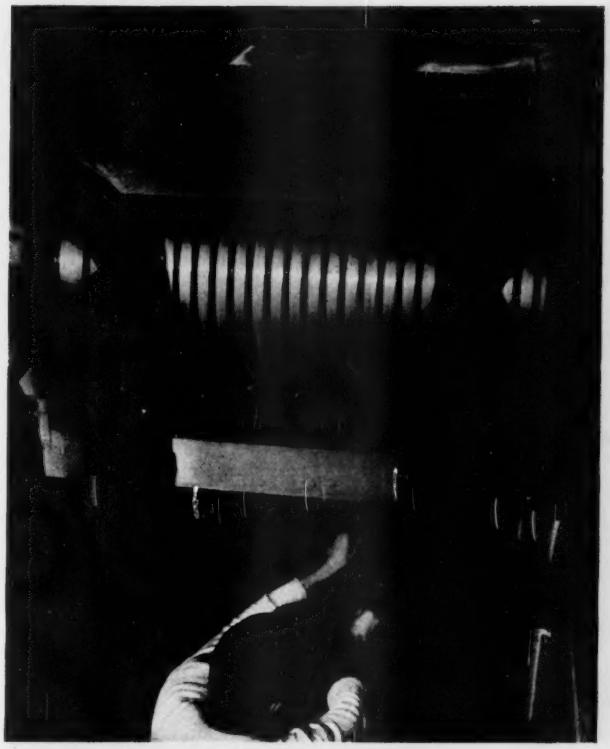
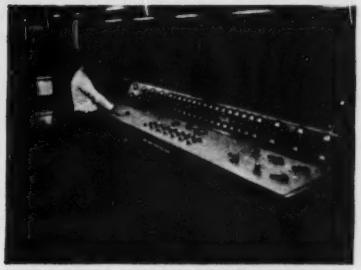


25 strands of steel wire start on their way to be electrolytically coated with copper, lead and brass.

Part of the 600 foot long electroforming machines where wires go through successive baths of plating solutions.



Console of controls for entire process is readily operated when necessary, even though seldom used in the almost fully automatic operation.

ENGINEERING . . . with a pioneering twist

There's a real incentive in working out ways to do things that have never been done before. And problems in pioneering are constantly cropping up at Western Electric—manufacturing unit of the Bell Telephone System.

For example: the revolutionary electroforming process dreamed up and made a reality by Western Electric engineers for making copper coated steel wire.

The big idea was this: Could a process be developed in which successive coats of copper, lead and brass would be deposited on steel wire electrolytically in one continuous operation?

Engineers of varied skills—electrical, mechanical, chemical, metallurgical, civil—went to work as a team. After solving many problems, they came up with a process that makes better, stronger wire at lower cost—does it at the rate of 1¾ billion feet per year.

Recent developments such as microwave radio relay networks for telephone calls and television programs—operator and customer dialing of long distance calls—secret electronic equipment for the Armed Forces—promise an ever-widening field for young engineers of varied training at Western Electric.

Western Electric

A UNIT OF THE BELL SYSTEM SINCE 1882

No. 1 in a Series

The Importance of Cable Engineering and Design

Cable engineering is concerned with the design and use of wires and cables to direct the flow of electrical energy from its source to the point of utilization. It is generally more economical to generate electric power in relatively large blocks at strategically located power plants and to transmit it over relatively long distances than to generate in small quantities where it is used.

There are, therefore, two general types of wires and cables used in the electrical industry:

(a) those used for power transmission, usually at voltages above 22 kilovolts,

(b) those used for power distribution at lower voltages.

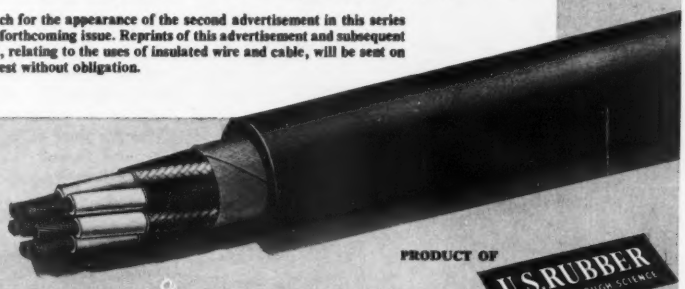
Cables used for power transmission are generally single conductors with no insulation. They are supported on insulators above ground at such separations or spacings that the air provides the required insulation. For power distribution, on the other hand, where the space occupied by the power line is important, insulated cables are used. This discussion deals with the design and use of insulated wires and cables for power distribution systems.

Insulated distribution cables carry power from the transformer stations along the transmission lines to its point of ultimate utilization. The voltages at which power is distributed vary from about 15 kilovolts to 115 volts used in individual homes. The higher voltages are used for the distribution of relatively large amounts of power from the transformer stations to substations nearer the points of utilization, such as industrial plants, where it is transformed to low or utilization voltages, either alternating or direct current. Large quantities of electric power are distributed in this way and the value of the distribution equipment required is great. The value of the insulated conductors, including those for both portable or stationary installations, probably exceeds that of any other single item used in power distribution.

The design and operation of insulated conductors and distribution systems are of great public and commercial importance. The primary function of insulated cable engineering and design is to provide safe, adequate, reliable and pleasant appearing distribution systems. Electric power is so extensively used in modern life that interruptions to it are serious. The failure of electrical power in an industrial plant throws people out of work and reduces production.

The appearance or sightliness of cables installed overhead in a community is important and is attained chiefly by installing such cables with a small and uniform sag from pole to pole.

Watch for the appearance of the second advertisement in this series in a forthcoming issue. Reprints of this advertisement and subsequent ones, relating to the uses of insulated wire and cable, will be sent on request without obligation.



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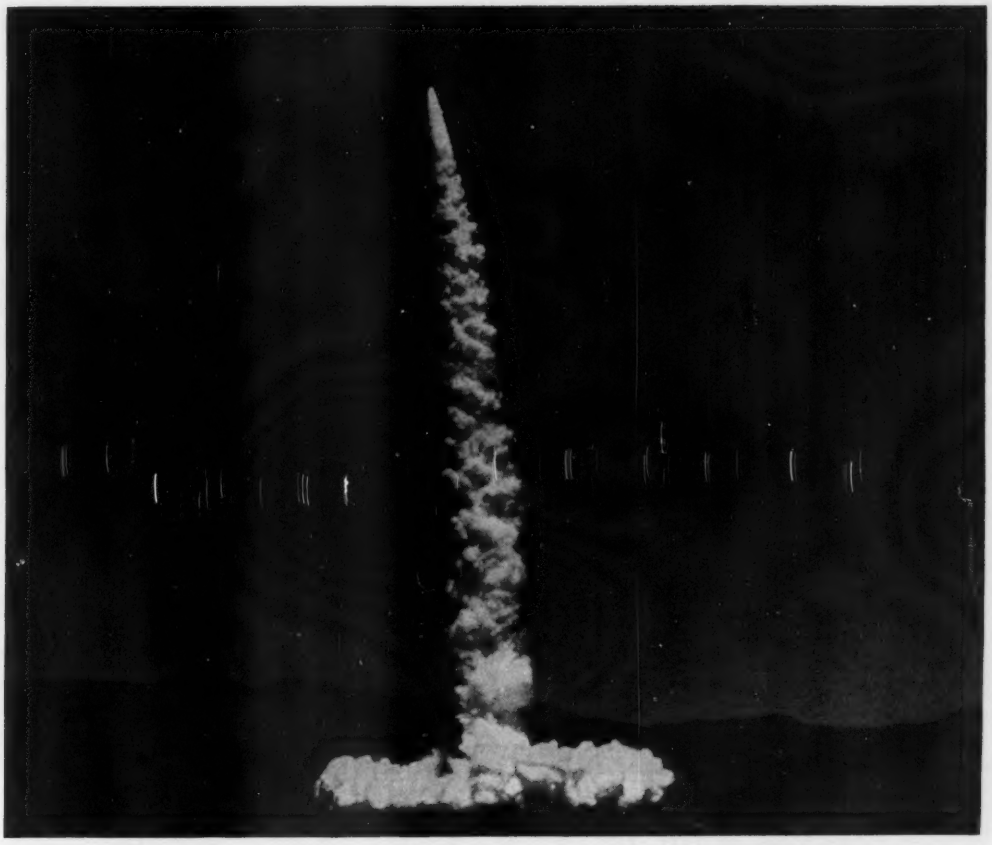

Engineers get ahead at Boeing

A major guided missile program is just one of Boeing's many projects-with-a-future. Other programs, which offer *you* plenty of room to get ahead in engineering, are America's first-announced jet transport project, research in supersonic flight and nuclear-powered aircraft, and development of the B-47 and B-52 jet bombers, the airplanes that have given Boeing more experience with multi-engine jets than any other company.

No other industry approaches this one in offering young engineers such a wide range of experience, or such breadth of application — from pure research to production design, all going on at once.

Aircraft development is such an integral part of our national life that young graduates can enter it with full expectation of a rewarding, long-term career. Boeing, for instance, is now in its 36th year of operation, and today employs more engineers than at the peak of World War II.

Boeing engineering activity is concentrated at Seattle in the Pacific Northwest and Wichita in the Midwest. Both communities offer fine fishing, hunting, golf, boating and other recreational opportunities. Both are fresh, modern cities with fine residential and shopping districts, and schools of higher learning where engineers can study for advanced degrees.

There are openings in ALL branches of engineering (mechanical, civil, electrical, aeronautical and related fields) for work in aircraft **DESIGN, DEVELOPMENT, PRODUCTION, RESEARCH and TOOLING.** Also for servo-mechanism and electronics designers and analysts, and physicists and mathematicians with advanced degrees.

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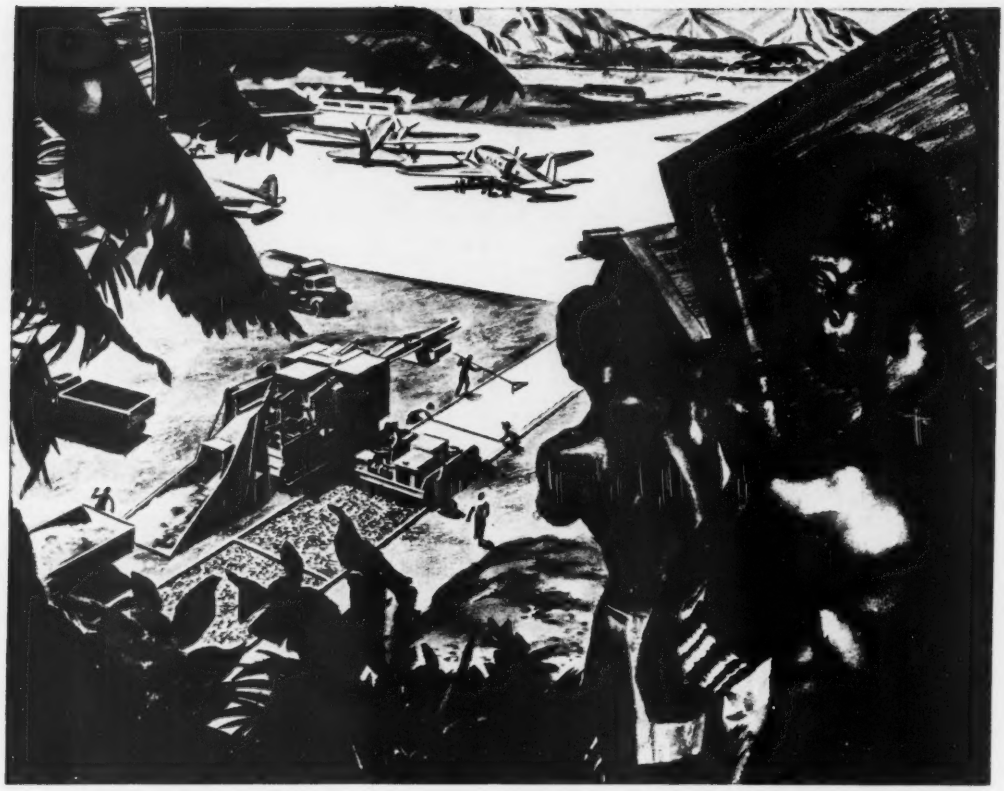

Takes a lot to lay a carpet in the jungle

The scene is "darkest Africa".

But Africa is lightening. Man's quest for minerals, for new areas for agriculture and trade, is slashing ultra-modern, glaring-white air strips in once impenetrable jungle.

Those pavers, portable air compressors, pumps and air tools—such as you might see working a city street—are Worthington Blue Brutes going to "lay a carpet" in that hole in the jungle.

Thus, Worthington, a major producer of equipment for public works, industry and farm, brings the fruits of American technical genius to the strange places of the world.

And illustrates, too, how the unique American talent of *diversification* helps public, employees and stockholders. For Worthington makes many things—not just construction equipment and pumps, but also engines, water works machinery, power transmission, petroleum equipment, air conditioning and refrigeration, many others.

Such diversification builds *stability* . . . makes Worthington, 112 years old, a strong link in the chain of American business.

Worthington Corporation, formerly Worthington Pump and Machinery Corporation, Harrison, New Jersey.

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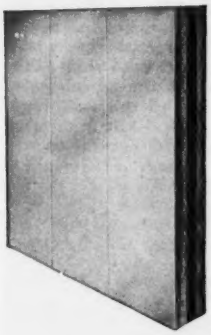
What's Happening at CRUCIBLE

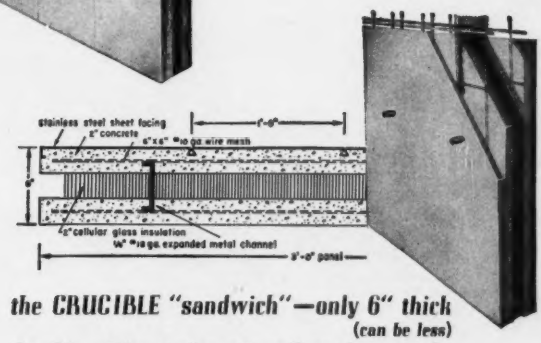
about stainless curtain walls

Modern construction methods have changed walls from the self-supporting type to a mere covering which does not support its own weight for more than one or two stories. Hence the definition of "curtain wall":—the facing or enclosure of the structural steel frame. This frame supports the entire weight of modern buildings.

The need has existed for a covering that would not only clothe the building, but be lightweight, economical and space saving. Because these requirements are more than adequately met with stainless steel curtain wall construction, this method is becoming increasingly popular with cost and space conscious owners, builders and architects.



the CRUCIBLE "sandwich"



the CRUCIBLE "sandwich"—only 6" thick
(can be less)

Crucible stainless steel curtain wall panels are in the form of 6-inch thick "sandwiches". The facing consists of flanged, light-gauge stainless steel sheets with a factory, or site-fabricated, sandwich consisting of cellular glass insulation between two layers of concrete with connecting reinforcing. Crucible 18-8 stainless as the outside face offers excellent resistance to weather and fire while providing eternal beauty with a minimum of maintenance; the inside face can be finished or painted to suit the requirements of modern building interiors. Since 18-8 is restricted in use, a good substitute material, type 430 stainless, now government decontrolled, offers the same benefits as 18-8 stainless.

moisture penetration

The unique characteristics of the cellular glass insulation stop moisture vapor migration from one face of the panel to the other. The cellular insulation properly designed and installed assures that condensation will not take place *anywhere* within the sandwich.

insulation

Although less than half as thick as the usual wall construction, this Crucible stainless steel panel construction has more than twice the insulating value. The "U" value (overall thermal conductivity) is approximately 0.15 BTU Hr./Sq.Ft./°F.

fire resistance

The Crucible sandwich met the requirements of a standard 4-hour fire test conducted in the testing laboratories of the National Bureau of Standards. This meets all old building codes and is double, or better, the requirements of modern enlightened building codes.

erection and fabrication

Since a building frame is not precision built, the attachment of the panel walls to the frame is done with fastening devices that provide necessary 3-dimensional adjustment. Panels can be made at the building site, and a 24-hour casting-to-fastening cycle is possible.

technical service available

Though the use of some stainless steel is now restricted, Crucible metallurgists and development personnel are continuing to investigate improved methods of curtain wall and other construction so that better buildings can be built when stainless is more freely available. For more information write: CRUCIBLE STEEL COMPANY OF AMERICA, General Sales and Operating Offices, Oliver Building, Pittsburgh, Penna.

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flight without motion

By John Rossettos, '55

The Testing of Airplane Models in Wind Tunnels

Aerodynamics is the science of air in motion and its effect on bodies immersed in its flow. The practical applications of this science involve the shaping of bodies and surfaces so that they will offer minimum resistance to air flow. This means that these bodies are enabled to travel through the air at the highest possible velocity with the least expenditure of energy.

An obvious handicap in the application of aerodynamic laws is the fact that air is invisible which makes it practically impossible to see its path around bodies or such phenomena as eddies, turbulence, and separation. Ship designers at least can observe wave shapes and their travel around the hulls of model ships. Airplane designers are not this fortunate. At first "build, try, and tear" methods were used. Today, however, the expense involved in aircraft construction warrants a more exact determination of what will happen in the air before any design can be considered.

Extremely delicate work is now being carried out in such laboratories as those of the National Advisory Committee for Aeronautics, Massachusetts Institute of Technology, California Institute of Technology, National Physical Laboratory in England, and the aeronautical labs in Göttingen, Germany.

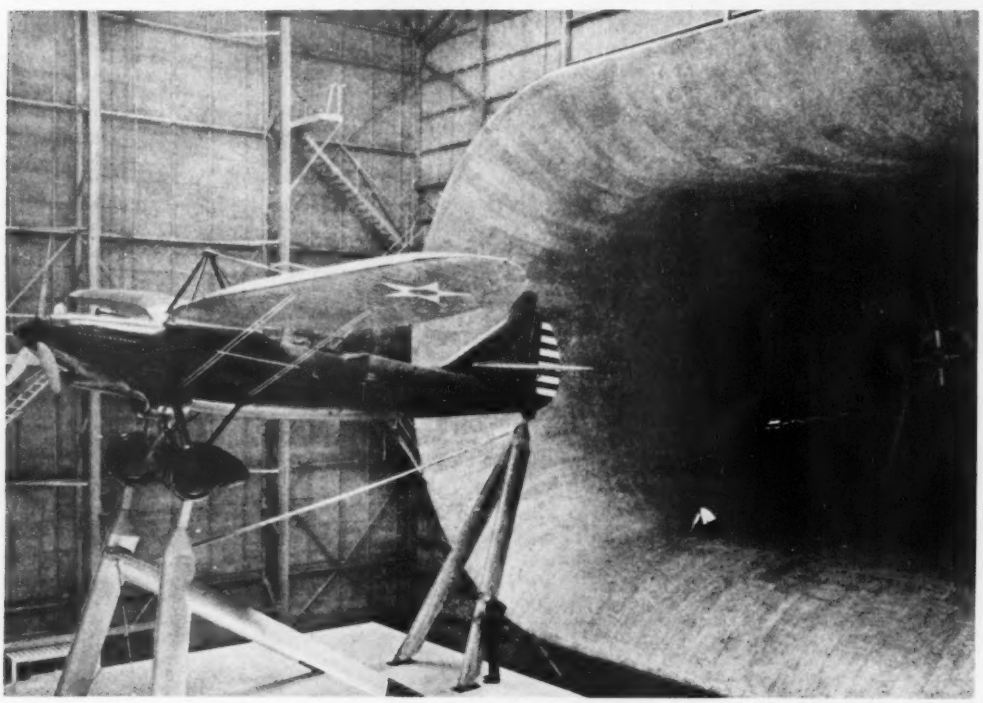
All this work depends on a dimensionless or pure number named after Reynolds. It is equal to Vl/ν; where V is a velocity, l is a length of the body and ν is the kinematic viscosity of the fluid in motion. Dimensional analysis has led to a very definite form for the relation between forces due to motion of solids through fluids and the physical parameters involved. The relation is usually written as:

$$F = c_f \tfrac{1}{2} \rho V^2 s$$

where the coefficient c_f is a function of the Reynolds number above, and s is a characteristic area proportional to l^2.

The problem of finding and interpreting experimental results is greatly simplified by use of this relation. For a given shape of body at a particular altitude one need only determine how c_f varies with R (Reynolds number). Then for any combination of size, speed, viscosity, and density, the force F can be calculated with the above equation.

N.A.C.A. full-scale wind tunnel, Langley Field, Virginia.



The aeronautical engineers concern themselves with the significant forces of "lift," which is perpendicular to the direction of motion, "drag," which is in the direction of motion, and the "pitching moment," which is a moment about an axis perpendicular to the direction of motion and to the lift vector. This pitching moment tends to raise the leading edge of the body. Each of these forces has a corresponding coefficient as shown below, which depends on R.

$$C_L = \frac{\text{LIFT}}{\frac{1}{2}\rho V^2 s} = \text{Lift coefficient;}$$

$$C_D = \frac{\text{DRAG}}{\frac{1}{2}\rho V^2 s} = \text{Drag coeff.;}$$

$$C_M = \frac{\text{Pitching moment}}{\frac{1}{2}\rho V^2 sc}$$

Pitching moment coefficient "c" in the last equation is the mean chord of a wing section. One may think of the Reynolds number as determining a quality of air that makes it more or less resistant to dynamic shear. All the coefficients, however, including R, are dependent on the shape and attitude of the body under consideration. For a given airfoil its attitude is the angle between the direction of motion and a chord line, usually referred to as the angle of attack.

One immediately realizes from this discussion that if a model is placed in flowing air and the forces on it are determined, the coefficients can be calculated. One also realizes that a prototype having an R identical with the model has the same coefficients. Also since its dimensions are known, the forces can be calculated. This is a basis for aerodynamic experiments.

There are two methods of approaching the problem. The first is to tow the body tested through air and determine the forces exerted on the towing member. The second is to blow air past a stationary body and calculate the forces on the body as will soon be discussed. The first method is used by the Guggenheim Airship Institute at Akron, Ohio. There airplane models are towed in air by being rotated at high speed. The second method is by far the most common, since it is the relative motion of the object and the air that is important. A wind tunnel is used for moving air relative to the model. There are many different types, but all have the purpose of creating a very uniform air stream with high velocity over the working section in which a model is mounted. The supporting members of a model are attached to a system of calibrated balances which give the forces and moments acting on the model. From

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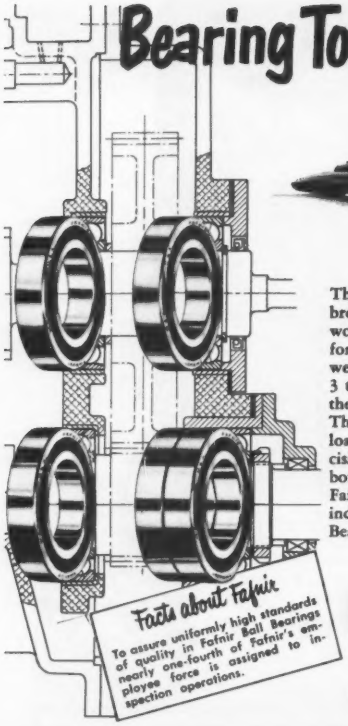

Bearing Torture Chamber of a World Champion

Through this spur gear box, a record-breaking speedboat, SLO-MO-SHUN, set a world's straightaway record of 160.3 mph for a mile. Although the straightaway runs were made with a damaged drive shaft, the 3 to 1 step-up ratio in the gear box turned the output (propeller) shaft 11,100 r.p.m. The tandem duplex bearing took a thrust load of 4600 pounds. 5 Fafnir Super-Precision Ball Bearings are used in the gear box . . . another indication that the use of Fafnir Bearings is not limited to one or two industries but is industry-wide. The Fafnir Bearing Company, New Britain, Conn.

Facts about Fafnir

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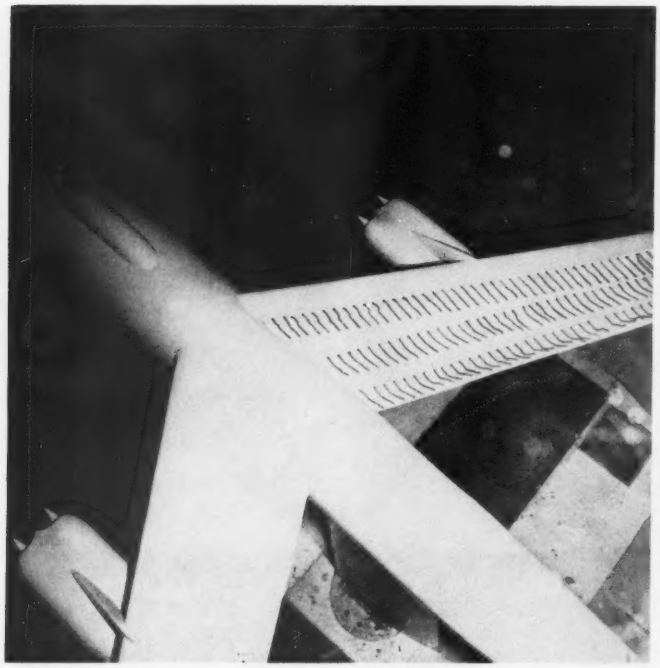

Tunnel model of B-47 Stratoget

flight without motion

the measured forces and the geometry of the model (*s* and *c*) and the velocity of the air, the dimensionless coefficients as discussed above can be calculated. Graphs, using various Reynolds numbers, are then constructed. Thereby a ready reference to performance data becomes available for design purposes.

Let us take a closer look at a wind tunnel. Designs for the tunnel can vary from the simple one used by the Wright Brothers to the more complicated systems employed today by the N.A.C.A. A very common and simple one is the open end tunnel and the N.P.L. balance. In this type of tunnel air is drawn through a tube by a powerful fan or propeller. Before the air goes over the model, a section of vanes or honeycombs straighten out the air flow making it approach a straight line or streamline. The model is attached to a vertical supporting rod. Below the tunnel are two crossarms which can be supported on fulcrums. Any forces on the model, tending to lift it up or push it back, are balanced by weights on the crossarms, and the lift and drag forces at any given speed can be determined by the moments necessary on the balance arm. The moments are proportional to the balancing weights on the crossarm and the distance from the fulcrum. Figure 2 is a crude version of the open end tunnel. Other more elaborate tunnels maintaining the same balance principle are that of the open jet, used by universities and aeronautical companies. A six-blade adjustable propeller draws the air in with the aid of a two hundred horsepower motor. Guide vanes straighten the air disturbed by the blade torque. Honeycombs control the final flow. A venturi effect at the entrance cone increases the velocity of the air at the test section so that a range from 0 to 80 miles per hour is obtainable. There exist also a few full-scale wind tunnels but only government agencies have been financially able to build and operate them. In the United States such a tunnel is used by the N.A.C.A. at Langley Field, Virginia. A mean velocity of 118 miles per hour is obtained with two propellers of thirty-five feet five inches diameter. The driving motor is four thousand horsepower. Below the craft there is a complicated six-component type balance, which is linked to seven dial type scales. A solenoid-operated printing device fitted to the scales records all readings simultaneously by merely pushing a switch. Forces in three

direction are measured and computation of lift, drag, and the pitching, yawing, and rolling moments is thereby made possible.

The N.A.C.A. also operates a vertical wind tunnel. This was originally used for spinning tests on models whose maximum span is about thirty-six inches. Ordinary tunnels use metal or very hardwood models. The spin test models use balsa wood with silk covered wings. A spindle rotates the model and then is withdrawn as soon as the air velocity is sufficient to maintain the model at a definite height in the tunnel. A record of the test is usually made by a motion picture film.

The next question that arises is how the test data compares with the true data for the full-size craft in free air. There is a difference known as "scale effect." Some of the coefficients vary little with R in the region of interest and have a small scale effect. Others, however, have a large scale effect. It is necessary, therefore, to test models at a Reynolds number as near as possible to the expected full-size one. Now $R = Vl/\nu$. Since ν is equal for both the model and full-size craft, as it depends on air which is the same for both, then Vl_{model} must equal $Vl_{\text{full size}}$. The "l" of the full-size aircraft is obviously greater than that of the model; therefore the air over the model must be at a large velocity to maintain the same R. The variation of V in the tunnel not only involves expense, but with the large V required by modern high-speed airplane a high velocity of the air in the tunnel would be necessary, and too great a V would introduce "compressibility" effects which completely change the aerodynamic forces involved. Hence in order to get R (model) to equal R (full-size), the model size must very nearly approach that of the full-size airplane. But these tunnels are very expensive to build, as has already been mentioned, and only government labs maintain them. The only

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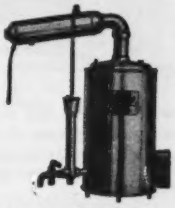

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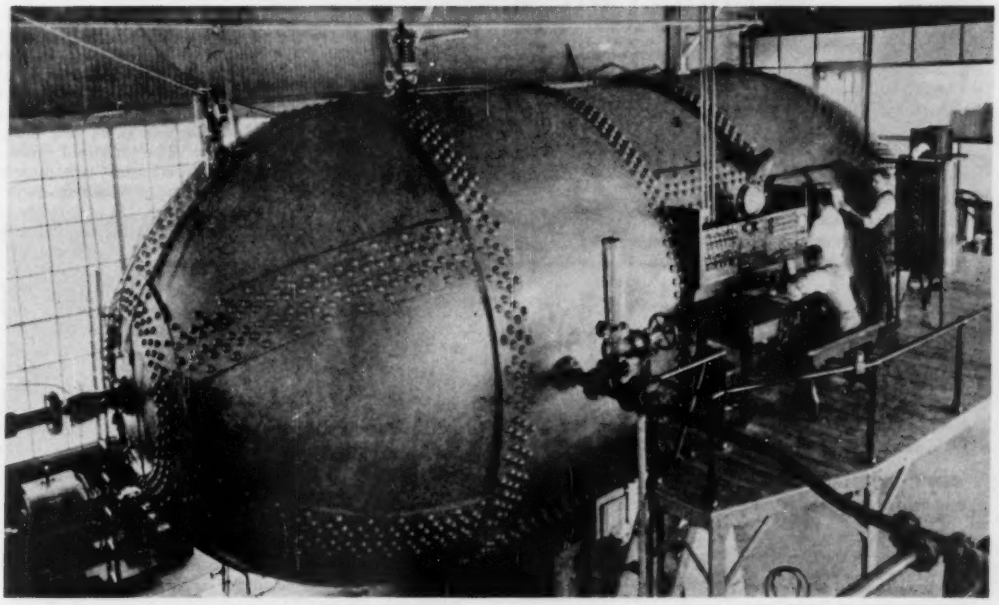
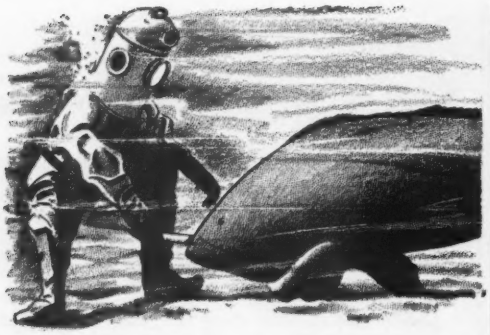
N.A.C.A. variable-density wind tunnel, Langley Field, Virginia.





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OKONITE insulated wires and cables

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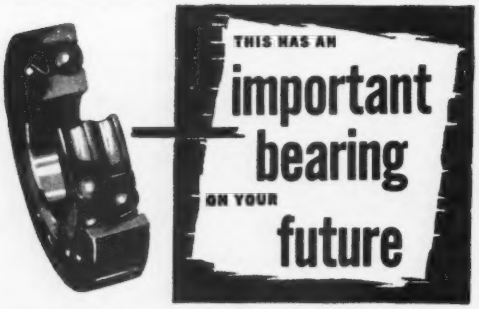

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flight without motion

remaining recourse is to vary the density of the air in the wind tunnel. Since $\nu = \mu/\rho$. where μ is the coefficient of friction, if we maintain ρ quite high then we can get a large R. In 1923 under the guidance of Dr. Max Munk, the N.A.C.A. completed the variable-density wind tunnel. This is similar to other tunnels except it is completely within a steel tank, constructed to withstand stresses better than 375 pounds per square inch. At 20 atmospheres, which is usually the normal operating pressure, ρ becomes 20 times as great as ρ in free air and the Reynolds number can be made 20 times larger with this variation.

Besides measuring forces, the wind tunnel can be especially constructed to enable visualization of the air as it flows around the model airfoil. This is done by injecting smoke or other visible medium into the air-

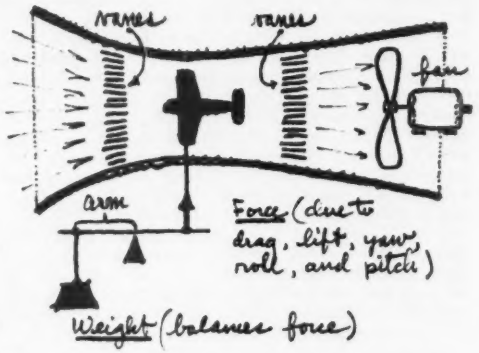

Figure 2. A simplified version of an open end wind tunnel and N.P.L. balance.

stream. In the Griswold Smoke Tunnel, rotten wood was smoldered to make solid white smoke streams which could be photographed satisfactorily. Vapor from evaporating dry ice is sometimes used, but it does not photograph as well. These "smoke streams" enable one to study such aerodynamic effects as lift, drag, downwash, and wing tip losses. The Griswold Smoke Tunnel is large, rectangular shaped and "two dimensional." The models span the entire space from the front to the back walls of the tunnel. It is capable of speeds of up to 120 feet per second. The fact that it is two dimensional means that only vertical and horizontal components are observed. As a result, certain phenomena can be investigated more clearly this way than in a three-dimensional flow. Certain preliminary investigations are made in a Griswold Tunnel before the three-dimensional wind tunnel is resorted to. Tests in the smoke tunnel are very easily and rapidly made. Although these tests are not as accurate as in other wind tunnels, they help to find out the definitely bad effects of poorly designed shapes in airfoils. Thus time and money can be saved in sorting out the sheep from the goats. Often a preliminary investigation in this smoke tunnel of a new aerodynamic device will show up primary causes of unsatisfactory effects and will thus point out the best way to a solution of the design problem. If more of this visualized aerodynamic research were carried out, certain limitations confronting designers might be surmounted and the resulting science of aerodynamics given new stature.

THE DU PONT DIGEST

JOB WITH A FUTURE—

Supervising Production

Varied experiences in a Du Pont chemical plant fit young engineers for higher responsibility

As was pointed out in the last issue of the *Digest*, Du Pont's many product lines afford men interested in production supervision experience in a wide variety of operations.

For a better idea of what the work involves, let's consider a specific case —the production of "Mycoban" sodium and calcium propionates, inhibitors used by bakeries to extend the mold-free life of bread and other baked goods.

Many of the problems encountered in the manufacture of "Mycoban" are similar to those arising in the manufacture of any Du Pont chemical. There is the same continuing effort to improve quality, while cutting costs through the better use of equipment, instrument controls and raw materials.

The supervisor works hand in hand with the plant technical section toward these goals. He also keeps himself informed on technological and economic trends affecting production and sales, finds explanations for out-of-line costs, and prepares plans and estimates for increasing production.

Such work obviously calls for a sound technical background. In addition, however, considerable administrative ability is needed. A supervisor must be able to *supervise*. His duties include keeping people under him informed about long-range changes in company policy and assuming responsibility for their safety and morale.

Process Control Engineer *W. L. Morgan (at left), B.S. in Ch., West Virginia Wesleyan '37, observes packing characteristics of "Mycoban" powder as it comes from the loading hopper.*

Production Supervisor *Robert B. McCue (at right), B.S. in Ch. E., West Virginia '38, and plant laboratory shift-leader J. P. Quarles, B.S. in Ch. E., Lehigh '38, discuss analysis of a product sample.*

The unusual problems encountered in "Mycoban" production are largely due to the seasonal nature of its sales. Its greatest use is in the hot, humid months, or from late spring to early fall. For this reason:

1. Production and warehouse inventories of "Mycoban" must be carefully balanced against sales forecasts. The supervisor gathers necessary background information for this operation.

2. Production needs, including manpower, equipment and materials, must likewise be planned to meet sales forecasts.

3. Maintenance, including a yearly hydrostatic test of the plant, must be scheduled with the plant maintenance supervisor for the minimum interference with peak-season production. Emergency maintenance must be kept down by carefully planned preventive maintenance.

As you can see, production supervisors have a broad field of activity at Du Pont. The experience gained in this job will prepare an ambitious man for advancement to positions of still higher responsibility.

YOU'LL WANT to read "Chemical Engineers at Du Pont." Explains opportunities in research, development, production, sales, administration and management. For copy, write: 2521 Nemours Building, Wilmington, Del.

DU PONT

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speech synthesis

By Kenneth Klopf, '56

The distinguishing characteristic between man and the lower animals is intelligence. Man's major information transmitting vehicle from prehistoric times to the present has been speech. It is natural that man should seek more knowledge about speech and how it is produced. One of the methods of increasing this knowledge is to synthesize the human vocal tract and speech making apparatus. Some of the machines and apparatus used in speech synthesis will be described in this article.

The importance of speech in conveying intelligence is responsible for the ancient gods being able to talk to humans. The ancient priests and shammans profited from the belief that the gods could speak. Some idols were constructed with secret channels within them that conveyed the voice of a hidden man to the mouth of the idol. In the sixteenth and seventeenth century men like Francis Bacon constructed dummies with hidden speaking tubes so that the effigy would appear to be able to speak. Undoubtedly the art of ventriloquism as we know it today had its start as a method of deception as practiced by the ancients.

At the end of the eighteenth century Wolfgang von Kempeler, a Hungarian, developed a successful speaking machine. Kempeler was a master craftsman with what could be called a flair for the dramatic. At one time he constructed an automatic chess-playing machine which played a very good game. This chess robot was demonstrated in the major cities of Europe where it made quite a sensation. The machine was supposed to have beaten Napoleon at this game of skill. Many papers were written attempting to explain the machine's apparatus, but in reality a small man was concealed within the apparatus to operate the robot. Strong magnets were concealed within each chess piece so that iron balls below the chess board indicated when and where a move had been made. Despite this deception the skill with which the apparatus was constructed attested to the craftsmanship of Kempeler.

Kempeler became interested in the formation of speech sounds and carefully studied the operation of the human vocal apparatus. By carefully studying his own vocal apparatus and its shape for each sound Kempeler constructed tables giving the size of the mouth opening and tongue channel opening for most of the sounds of the German language.

Prior to Kempeler various sound alphabets were constructed, but they usually consisted of inaccurate vocal tract sketches of the mouth cavity region showing the positions of the tract for each sound. In Kempeler's book the sounds were given with information referring to the relative size of the mouth opening and tongue channel opening. A relative scale was used increasing from one to five. The mouth opening information given in his book for the vowel sounds a, e, i, o, u are respectively 5, 4, 3, 2, 1.

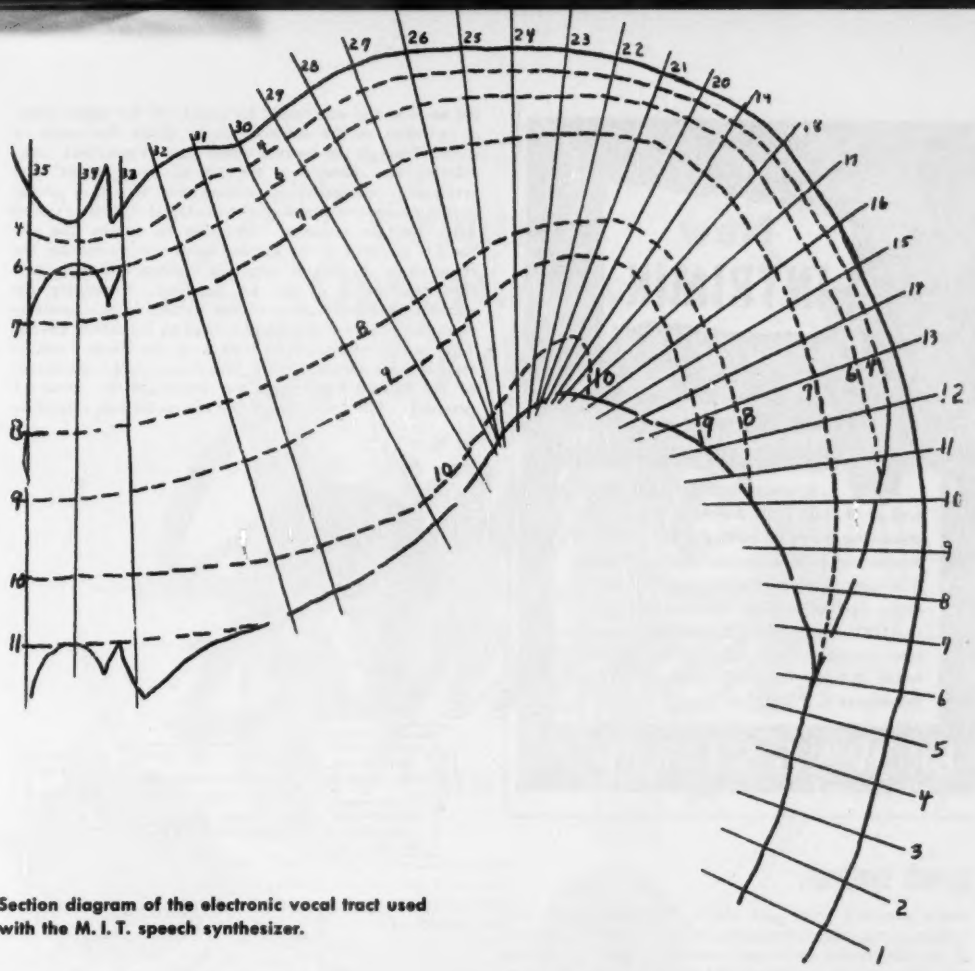
From Kempeler's period to the present many other sound alphabets have been constructed upon similar principles. Due to further research on the vocal tract, these alphabets are more accurate than their predecessors and are usually constructed for certain specialized needs. Notable among the men who constructed a few of the sound alphabets are Alexander Graham Bell and his father, Alexander Melville Bell.

In Kempeler's early speaking-machine work he constructed separate boxes or acoustical cavities which were shaped to resonate properly when a reed was set into vibration. Later he used one cavity for all the vowel sounds and changed the output sound by cupping his hands differently about the output side of the cavity. Kempeler found that although the vibrating reed was rich in harmonics the sound output of the cavities varied little in key and pitch. Despite this handicap the sounds were still recognizable. Kempeler attempted various systems to change the natural frequency of the vibrating reed but he met with little practical success. In Kempeler's final speaking machine he used the baritone reed from a set of bagpipes to simulate the vocal cords. Later experimenters, however, developed workable changing pitch reeds.

Kempeler's speaking machine was one of the first successful mechanical analogues of the human vocal tract. The system was a few feet high and consisted of four main elements; a bellows; a wind box; a vibrating reed; and various cavities and channels and openings designed to develop the proper sounds. The bellows simulated the abdominal muscles; the wind box simulated the lungs; the vibrating reed the vocal cords; and the cavities, channels, and openings the vocal cavities and constrictions. The machine was operated, or played, by the use of both arms and hands of the operator, and with one stroke of the bellows was capable of producing short phrases of approximately six syllables. The formation of the sound "f" was made with all openings of the speaking machine closed and the air escaping through the random leakages of the system.

After Kempeler many other speaking machines were made utilizing various principles. Further improvements were made in the acoustical pipe system. A system utilizing tuning forks was constructed by von Helmholtz, and Koenig used a shaped siren system. R. R. Riesz, a contemporary worker, developed the artificial larynx (a vibrating reed) which is used to substitute for the vocal cords in the actual human vocal tract. The artificial larynx is employed when the human vocal cords have been removed or damaged.

When the electronic age was ushered in by the development of the vacuum tube, speech synthesizers were developed which were electrical analogues of the human vocal tract or that produced sounds which closely simulated those emitted from the human vocal tract. The VODER developed by Dudley was demonstrated at the San Francisco and New York World's Fairs. The VODER was an electrical simulation of the vocal tract and consisted of a "white noise" generator for fricative sounds ("white noise" contains all audible frequencies), a relaxation oscillation to simulate the vocal cords, and an electrical network of resonance controls to control the input white noise and the har-



Section diagram of the electronic vocal tract used with the M. I. T. speech synthesizer.

monic output of the relaxation oscillator to produce the same sound as the vocal cavities would. The output of the resonance control circuit was applied through an amplifier and sent to the loudspeaker.

In 1950 H. K. Dunn of the Bell Telephone Laboratories published a paper dealing with an electrical vocal tract designed to simulate the vowel sounds. This system treated the vocal tract as a series of cylindrical sections or acoustic lines, using artificial transmission lines as analogues of the acoustic lines. The advantage of using the artificial transmission lines lies in their ability to pass harmonics as well as the fundamental frequency, thereby increasing the quality of the output sound. The computation of the transmission line sections are complex however, due to the interaction of each section on its adjacent sections. The dimensions for the cavities were taken from physical measurements of the vocal tract and in addition x-ray photographs were used to obtain measurements in the less accessible regions.

The electrical vocal tract which Dunn developed consisted of a simplification of the human vocal cavities. Only four sections were used, but at the time the tract was an appreciable advancement of the contemporary speech synthesizers. The system consisted of two main cavities which were an approximation of the complex shapes of the throat and mouth cavities. A small connecting cavity between the throat and mouth cavities simulated the hump of the tongue, while another small cavity simulated the constriction due to the lips. The output of this cavity was then applied to the speaker system. The artificial transmission line analogue of the acoustical cavities consisted of a separate "T" network for each cavity.

At M. I. T. the electrical analogue of the vocal tract was advanced still further by the development and construction in the latter part of 1951 and early 1952 of an electronic vocal tract utilizing thirty-four sections as compared to the four used in the above synthesizer. The increase in the number of sections resulted in a much closer approximation to the actual vocal tract and by changing the parameters of these sections a much more realistic output sound was obtained. Other refinements added also enabled the production of consonant sounds in addition to the vowel-like sounds. Research is also being done on the simulation of the stop sounds, which in the human vocal tract are formed by air under pressure being released suddenly.

The artificial transmission line sections are numbered from one to thirty-five as shown on the section

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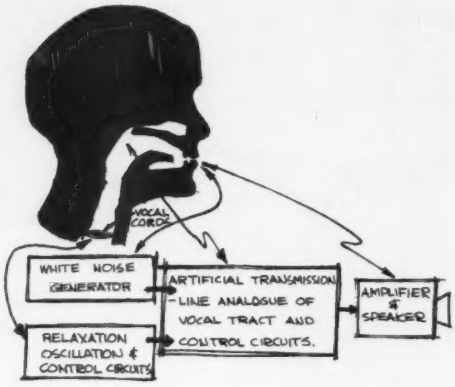
BROWN & SHARPE

speech synthesis

chart, starting from just above the vocal cords and ending at the constriction due to the lips. The length of the electronic vocal tract may be varied by cutting out the sections (cavities) not desired. The switches used for this purpose are immediately above the top bank of thirty-six switches. The switches above this row are used to control the relaxation oscillator circuits which simulate the vocal cords. The bottom bank of thirty-six switches is employed to change the cross-sectional area of each artificial transmission line section. Each one of these switches has ten positions with each position corresponding to a different cross-sectional area. The upper bank of thirty-six switches changes the losses in each transmission line section to correspond to the acoustical losses encountered in the actual vocal tract when the dimensions of the cavities are changed. When the cross-sectional area of one section is decreased, the switch corresponding to that section in the upper bank is positioned to increase the losses of that section. When fricative sounds are to be generated white noise is inserted into the sections where the sounds are generated in the actual vocal tract. When the sound "f" is to be simulated the white noise is inserted in sections thirty-three or thirty-four; when sounds similar to "k" are produced the white noise is inserted in the proper sections lying roughly in the range from fifteen to twenty-three.

The artificial transmission line sections consist of pi networks composed of an inductance, two capacitors, and two resistors. The resistors control the losses in the section and are varied by means of the upper bank of switches on the control panel. Since the speed of sound through the human vocal tract is constant (considering the density of the air to be constant) the artificial transmission line section must also have propagation properties enabling the electrical signals to travel with constant velocity. In order to obtain this end the LC product of the section must always remain the same since the travel time per section depends upon the square root of the LC product. Changing the characteristic resistance of the section is analagous to changing the cross-sectional area of an acoustical cavity. This is accomplished by means of the lower bank of switches, which change the inductance and capacitance of the section but which also maintain the same LC product. The formula for the characteristic resistance is: $R_c = \sqrt{\frac{L}{C}}$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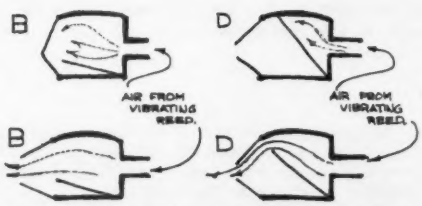
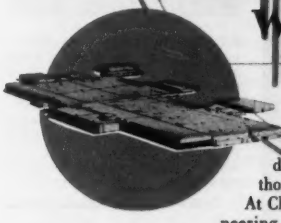


Wolfgang von Kempelen's early speech synthesis cavities. *Above:* Illustrating the plosive formation of the sounds "B" and "D."

The research being carried on in this subject may result in better usage of the radio spectrum for speech communication. At present a band-width of approximately five thousand cycles is necessary to transmit the speech spectrum for intelligible reception. This band-width can be reduced by transmitting signals representing the position of the vocal tract during speech. The frequencies of the vocal tract movements are much lower than the frequencies present in the speech spectrum so that a great saving in band-width could be accomplished.

The studies are also valuable to the linguist, providing him with positional information of the vocal tract for different sounds and also allowing an extension of the work now being done to teach the deaf to speak.

Greater Opportunity for the Creative Engineer with Chance Vought



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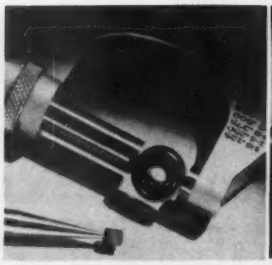

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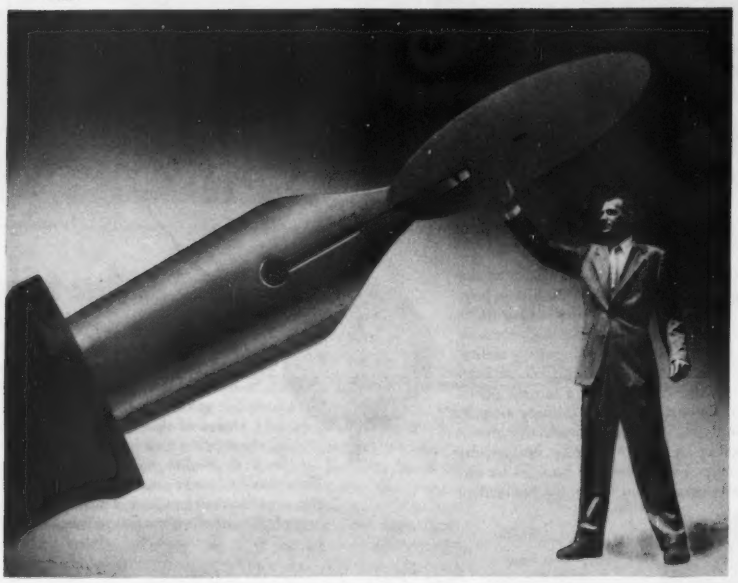

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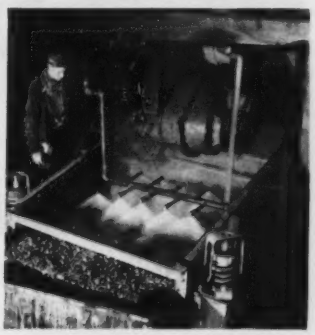

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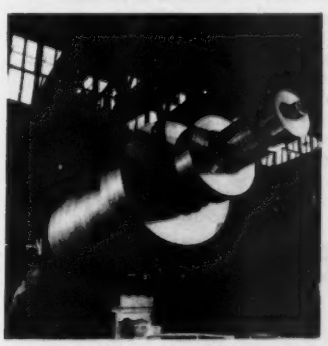

Rough-machined turbine spindle for 120,000-kw steam turbine. Calculating torsional stress and critical speed on shafts like these is part of Baird's job.

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1. It's well established, having been started in 1904. A large percentage of the management group are graduates of the course.

2. The course offers a maximum of 24 months' training.

3. The graduate engineer may choose the kind of work he wants to do: design, engineering, research, production, sales, erection, service, etc.

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5. He will have individual attention and guidance in working out his training program.

6. The program has as its objective the right job for the right man. As he gets experience in different training locations he can alter his course of training to match changing interests.

7. For information watch for the Allis-Chalmers representative visiting your campus, or call an Allis-Chalmers district office, or write Graduate Training Section, Allis-Chalmers, Milwaukee 1, Wisconsin.

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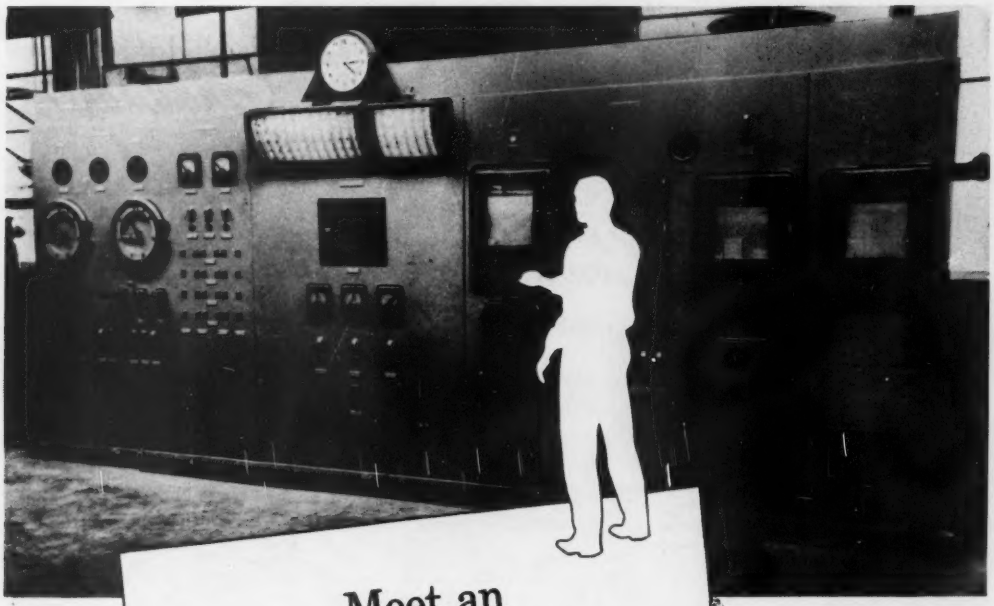

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You're especially happy about your next stop, because they got their first L&N instrument when the manager "bought" your analysis and recommendation for control of a galvanizing kettle-furnace . . . Now, he wants to know how you'd improve the control of a malleableizing furnace.

Back at the office, you talk things over with another sales engineer, who supervises your work. He verifies your ideas about both the controls you discussed with customers; suggests you check one of them with the district manager, in case that new accessory from the home office should be included . . . And he has a request that you call at an aircraft plant tomorrow or the next day.

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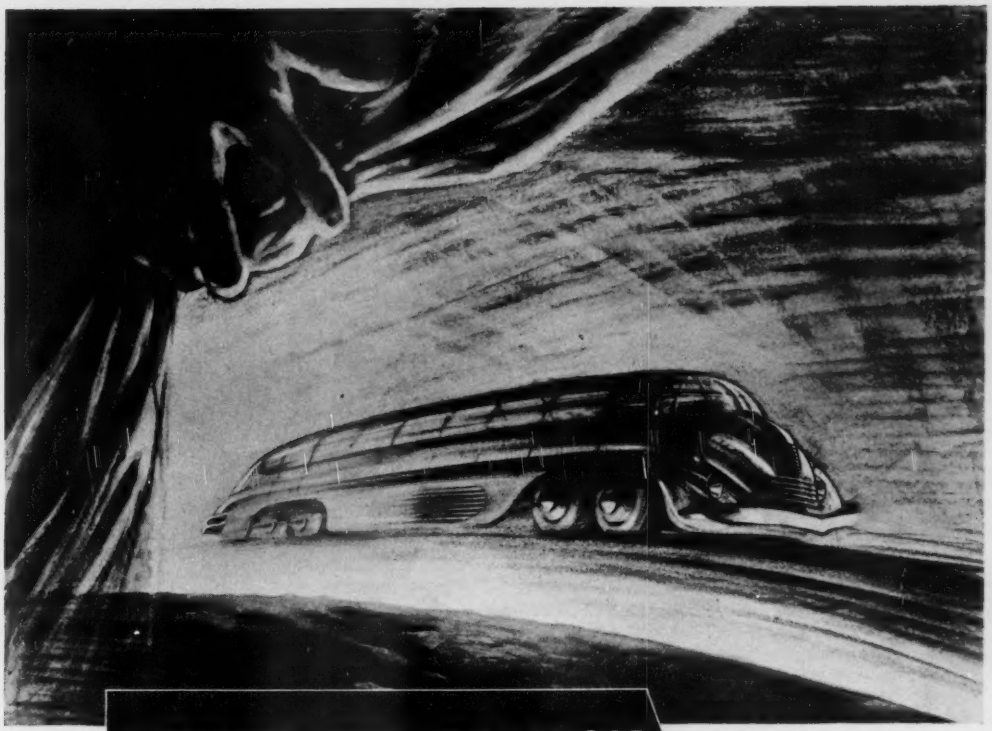

BEYOND THE HORIZON....

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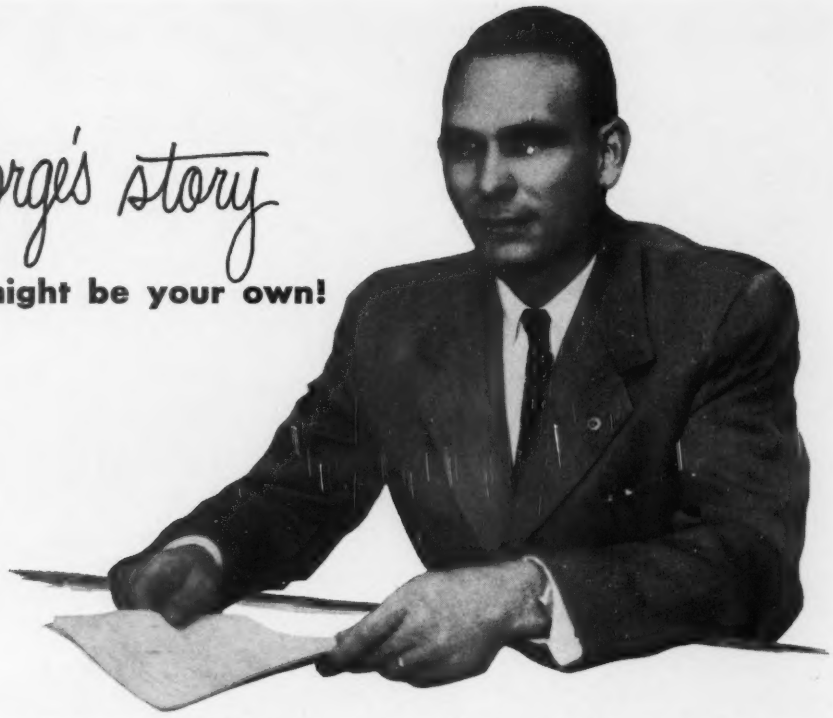

George L. Cobb is chief engineer of Columbia-Southern's plant at Natrium, West Virginia. He holds the responsible job of supervising the activities of maintenance, engineering and construction. He's a valued member of the Columbia-Southern organization.

Cobb started as a maintenance engineer six years ago, became assistant maintenance superintendent, then was tapped for his present job. But Cobb's story starts before that.

George attended Arkansas A&M and later Alabama Polytechnic Institute as a student in mechanical engineering. He received his degree in 1944, then served in the armed forces for two years.

Immediately upon his return, he sent his personal resume to 34 companies and received replies from 31 of them. He spent one month travelling over 12,000 miles investigating each promising opportunity which included a meeting with the Columbia-Southern people. Many offers were extremely attractive, but Columbia-Southern suited him best.

Why Columbia-Southern? Well, here's what George says.

1. He liked Pittsburgh Plate Glass Company, the parent company, and its reputation.
2. He liked Natrium, West Virginia, and the community surrounding it.
3. Columbia-Southern offered the opportunity to do the type of work he was most interested in—plant maintenance.

Cobb's advice to technical graduates today—"Look for job satisfaction—something one is best suited for. If a man doesn't like his job, he will be neither happy nor successful with it. I've traveled a great deal and have never found a more cooperative group to work with than the people at Natrium. I feel that holds more men to our organization than any other of several important considerations."

Columbia-Southern has opportunities for graduates in all business and technical fields including engineering, research and development, sales, plant design, mining, construction, maintenance, production, accounting, transportation and related fields.

You are invited to write now for further information at our Pittsburgh address or any of the plants.

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SUBSIDIARY OF PITTSBURGH PLATE GLASS COMPANY
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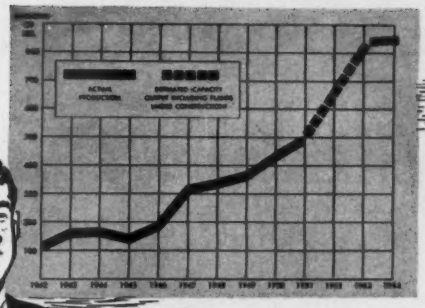

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Settling tanks, where impurities are separated from sodium aluminate

Tube drawing, one of many mill operations at Reynolds

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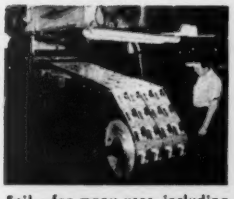

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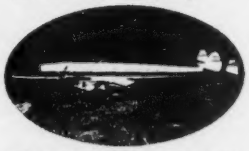

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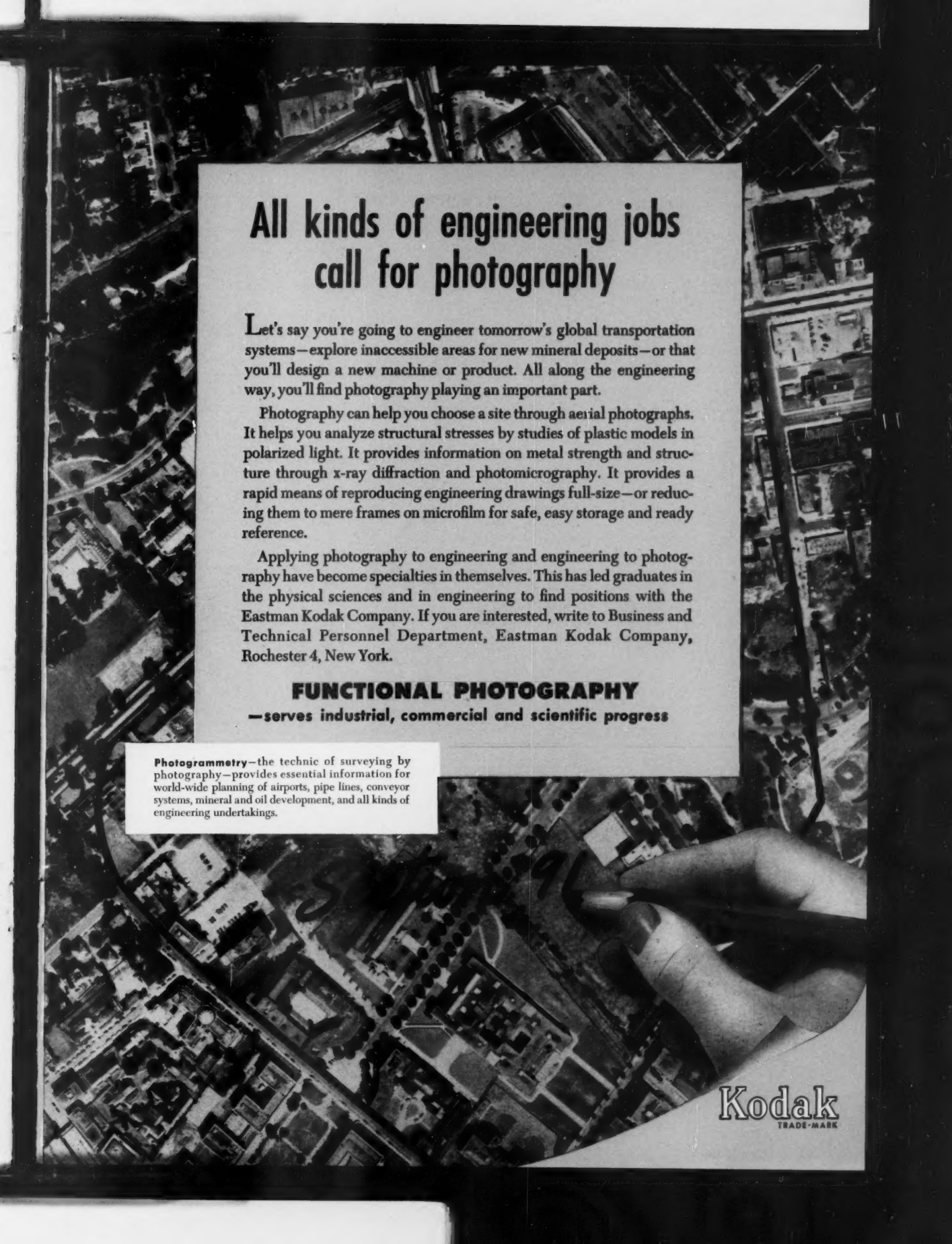

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MY QUESTION TO THE G-E STUDENT INFORMATION PANEL:

"What educational training opportunities are available to engineers in General Electric?"

. . . JAMES H. ROBBINS, University of Florida, 1953

The answer to Mr. Robbins' question, presented at a student information meeting held in July, 1952 between G-E personnel and representative college students, is printed below. If you have a question you would like answered, or seek further information about General Electric, mail your request to College Editor, Dept. 221–6, General Electric Co., Schenectady, N. Y.

M. M. BORING, *Engineering Services Division* . . . In General Electric the engineer has his choice of engaging in either Company education programs or in graduate study in nearby colleges and universities.

The Company programs are based on material directed toward better fitting the engineer for a career with the Company. He will gain first-hand knowledge of industry, come in contact with many different products and types of work, and associate with top-flight engineers.

General Electric actively encourages college graduate study, and when this study applies to the individual's work, on approval by his departmental manager, provisions are made for refunds of one-half tuition costs upon satisfactory completion of courses.

The technical education programs in G.E. may be divided into two main categories: the advanced technical programs, where carefully selected students (any engineer may apply) are given intensive training; and the general and specialized technical courses, available to all Company engineers.

The objective of the advanced technical programs—Creative Engineering, Advanced Engineering, and Process Technology—is to impart an understanding of fundamental scientific principles and their application to particular problems, as well as to encourage a basic approach to these problems and promote confidence in the engineer's own ability.

The Creative Engineering Program is directed toward developing creative and inventive abilities, and a logical approach to design problems by definition, search, selection, and evaluation.

Organized to develop top-flight engineers, the Advanced Engineering Program provides an opportunity to study fundamental physical principles and advanced mathematical methods in the areas of electrical and mechanical engineering.

The Process Technology Program, concerned with chemical, chemical engineering, and metallurgical fields, acquaints the engineer with laboratory and engineering groups, with activities in many locations, and with various product businesses of the Company.

The category that includes the general courses is designed to acquaint engineers with the engineering aspects of marketing, manufacturing, and application engineering as well as providing less intensive courses on fundamental principles. The specialized technical courses provide intensive study for engineers permanently assigned to operating departments in such fields as servomechanics, heat transfer, and magnetic design.

In addition, educational opportunities are offered engineers by our Manufacturing, Marketing, Employee and Plant Community Relations, and other divisions.

Besides having the opportunity for educational development, the engineer in General Electric is given a good job with plenty of responsibility, sound training for a lifetime career, opportunities for careers in widely varied phases of science and engineering, a good place in which to work, and a place in which to lead a well-rounded life.

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